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STUDIES ON SURFACE TAINT BUTTER

IV. DISTRIBUTION AND TAXONOMY OF *PSEUDOMONAS PUTREFACIENS*[1]

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Pseudomonas putrefaciens has been isolated from soil, water and various other sources (Table 1). Long and Hammer (7) expressed the opinion that, in those instances where the organism was isolated from pasteurized milk, it was introduced into the milk after pasteurization.

The present is a more complete report of the distribution of *Ps. putrefaciens* in Alberta creamery waters and butters than was previously given by Wolochow (9). Its habitat and characteristics are discussed in relation to taxonomy.

METHODS

The butter and water samples were plated on both nutrient gelatin and tryptone-beef-extract-glucose-2% skim milk medium and incubated at 10° to 15° C. Surface and sub-surface colonies were fished at random into litmus milk incubated at room temperature (about 21° C.) for periods varying from 5 to 14 days. The litmus milk cultures were then examined for change in reaction as indicated by the colour of the litmus, reduction of the litmus, proteolysis and odour. The incubation temperature of all experimental butters was 10° to 15° C., and the pasteurization of the cream was for 10 minutes at a minimum of 81.5° C.

DISTRIBUTION

Approximately 2500 random bacterial isolations were made in this way. *Ps. putrefaciens* was unique among these in causing the following combination of changes in litmus milk: rapid reduction of the litmus without change in reaction; proteolysis; and the production of an odour which suggests the odour of sweaty feet and is intensified when a few drops of the culture are allowed to dry on the fingers to the point of stickiness.

All isolations having this combination of characteristics were later identified as *Ps. putrefaciens*. All but 3 of these cultures were found to be able to produce a defect in experimental high-temperature pasteurized-cream butters which graded surface taint and was indistinguishable from commercial surface taint.

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From 12 creameries widely dispersed over the Province of Alberta 43 cultures of *Ps. putrefaciens* were isolated in this manner. The distribution of their sources is shown in Table 2. From Tables 1 and 2 it is clearly evident that *Ps. putrefaciens* is a soil and water form.

TABLE 1.—ISOLATIONS OF *Pseudomonas putrefaciens* BY VARIOUS INVESTIGATORS

Source	Number of instances	Authors
Soil	1	Long and Hammer (7)
Farm well water	6	Linneboe (5)
Creamery water	*	Loftus-Hills et al. (6)
	2	Cullity and Griffin (2)
	1	Claydon and Hammer (1)
	11	Wolochow (9)
	14	Linneboe (5)
	14	Long and Hammer (7)
	14	Jamieson (4)
Stream, lake and roadside water	44	Long and Hammer (7)
Creamery floors, sewers and equipment	*	Loftus-Hills et al. (6)
	1	Claydon and Hammer (1)
	*	Long and Hammer (7)
	*	Shadwick (8)
Raw milk and cream	*	Loftus-Hills et al. (6)
	5	Long and Hammer (7)
Pasteurized milk and cream	*	Loftus-Hills et al. (6)
	2	Long and Hammer (7)
Abnormal butter	6	Derby and Hammer (3)
	6	Wolochow (9)
	46	Claydon and Hammer (1)
	*	Linneboe (5)
	*	Long and Hammer (7)
Normal butter	3	Wolochow (9)
	2	Long and Hammer (7)

* Number of times found not stated.

TAXONOMY

Derby and Hammer (3) first isolated *Ps. putrefaciens* and tentatively named it *Achromobacter putrefaciens*. In the Fifth Edition of Bergey's Manual of Determinative Bacteriology the organism is listed in an appendix to the Family *Bacteriaceae* under the note that it "probably should be placed in some one of the genera included in the Family *Pseudomonadaceae*". Wolochow (10) expressed the opinion that it falls in the Family *Pseudomonadaceae*, Tribe *Pseudomonadeae*. More recently, Long and Hammer (7) have called the organism *Pseudomonas putrefaciens*.

This organism fits into the system of classification outlined in the Fifth Edition of Bergey's Manual of Determinative Bacteriology as follows (13):

Does not produce endospores. Is heterotrophic but capable of utilizing inorganic nitrogen. Is a soil and water form. Is gram-negative with a single polar flagellum.

Family III. *Pseudomonadaceae*

Straight rods.

Tribe II. *Pseudomonadeae*

The organism does not attack protamines or aromatic compounds (13) and there is no reason to assume that it is a plant pathogen. This leaves only the genus *Pseudomonas* in which it can be placed at present. However, it does not fit into this genus because it has not been shown to produce the necessary pigment, although a number of anomalies are already to be found in *Pseudomonas*. The need for an enlargement of the Tribe *Pseudomonadeae* is apparent and, indeed, the Chairman of the Board of Editor-Trustees of Bergey's Manual informs us that such revision is presently proceeding.

TABLE 2.—THE SOURCE DISTRIBUTION OF 43 ISOLATIONS OF *Pseudomonas putrefaciens*

Type of source	Surface taint butter	Normal butter	Incubated unworked butter	Well water*	Storage tank water	Total
Number of sources	2	3	4	9	2	
Number of isolations	5	4	8	15	11	43

* Including 6 isolations from 3 churn and butter washwaters of unstated source from 3 creameries.

Therefore, throughout this series of publications the organism is called *Pseudomonas putrefaciens* with recognition of the imminency of further taxonomic changes.

CONCLUSIONS

Pseudomonas putrefaciens, a soil and water organism, is widely distributed in the waters of Alberta. It has been found in Australia and over a large area in the United States.

Taxonomically this organism should be placed in the Family *Pseudomonadaceae*, Tribe *Pseudomonadeae* (Fifth Edition, Bergey's Manual of Determinative Bacteriology).

In the present series of publications the organism is tentatively called *Pseudomonas putrefaciens*. This classification is not in complete harmony with the characteristics outlined for this genus in the Fifth Edition of Bergey's Manual.

The need for revision of the genera in the Tribe *Pseudomonadeae* is made evident.

REFERENCES

1. Claydon, T. J. and B. W. Hammer. Bacteriology of butter. VIII. Relationship of *Achromobacter putrefaciens* to the putrid defect of butter. Iowa Agr. Exp. Sta. Res. Bull. 267. 1939.

2. Cullity, M. and D. G. Griffin. Rabbito or surface taint in butter. J. Dept. Agr. W. Australia. *15* (2nd series) : 137-147. 1938.

3. Derby, H. A. and B. W. Hammer. Bacteriology of butter. IV. Bacteriological studies on surface taint butter. Iowa Agr. Exp. Sta. Res. Bull. 145. 1931.

4. Jamieson, M. C. Water—churn sanitation—and butter flavour. Can. Dairy Ice Cream J. 20 : 20-22, 58, 60. 1941.

5. Linneboe, J. B. Water supplies in relation to surface taint butter. Sci. Agr. 21 : 133-138. 1940.

6. Loftus-Hills, Scharp and Searle. Cited by M. Cullity and D. G. Griffin, 1938. loc. cit. 1935.

7. Long, H. F. and B. W. Hammer. Classification of the organisms important in dairy products. III. *Pseudomonas putrefaciens*. Iowa Agr. Exp. Sta. Res. Bull. 285. 1941.

8. Shadwick, G. W. Cited by H. F. Long and B. W. Hammer. 1941. loc. cit.

9. Wolochow, H. Progress report on an investigation of surface taint butter to Alta. Dairymen's Assoc. Ann. Conv. 1939.

10. Wolochow, H. Studies on surface taint butter. Thesis, University of Alberta Library, Edmonton. 1940.

This series, "Studies on Surface Taint Butter", comprises the following titles:

11. I. Odour production by *Pseudomonas putrefaciens*. Sci. Agr. 22 : 277-286.

12. II. An odourous compound in skim milk cultures of *Pseudomonas putrefaciens*. Sci. Agr. 22 : 347-355.

13. III. Some further characteristics of *Pseudomonas putrefaciens*. Sci. Agr. 22 : 438-447. 1942.

14. IV. Distribution and taxonomy of *Pseudomonas putrefaciens*. Sci. Agr. 22 : 461-464.

15. V. The growth of *Pseudomonas putrefaciens* in butter. To be published.

16. VI. Other bacterial species as causal agents. To be published.

TOBACCO MOSAIC IN ONTARIO AND QUEBEC[1]

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For many years mosaic has been one of the most important diseases in the tobacco growing districts of Ontario and Quebec. With the great increase in acreage in recent years, mosaic became correspondingly more widespread, making it essential to familiarize growers with the sources of primary infection and manner of spread, so that more effective use may be made of suggested control measures.

In 1935 when tobacco virus research was initiated at the St. Catharines laboratory, there was no general agreement as to the factor or factors that were most important from the standpoint of initial infection and spread in the field. For instance, Valleau and Johnson (4) placed emphasis on the importance of the use of tobacco in any shape or form by the help; Lehman (2) emphasized cultural practices, while J. Johnson (1) stressed the importance of contaminated soil.

Therefore, the primary object of the present investigation was to ascertain the respective importance of these and other factors in connection with the incidence of mosaic in Ontario and Quebec. Realizing that the possible important sources of infection relate to (1) contaminated soil, (2) the living infected plant or disintegrating plant parts, (3) contaminated hands, tools and implements used in culture of the crop and (4) possible insect vectors, field and laboratory investigations were planned to ascertain the importance of the first three sources above.

MATERIALS AND METHODS

Though certain laboratory tests, especially in connection with contaminated soil, were carried out, the investigation was concerned mainly with field plots which were situated at Delhi and St. Catharines in Ontario and at L'Assomption and Farnham in Quebec. These plots, with a few exceptions, consisted of 200 plants, and unless stated otherwise, were planted on land new to tobacco or on land that had not grown tobacco for one or more years. The flue-cured varieties White Mammoth and Yellow Mammoth were used in Ontario and Quebec (1938) and the cigar-leaf varieties C. S. Pomeroy and Parfum d'Italie were used in Quebec.

The series of plots were located at two or more places in both Provinces, and were so laid out and supervised that, in so far as possible, contamination from outside sources was reduced to a minimum, except, of course, in those plots where such contamination was desirable. In addition, each individual experiment was carried out for three or more years to study the effect of environment on spread of mosaic.

In cultivated plots, the number of cultivations rarely exceeded four. In non-cultivated plots weeds were kept down by hand or by paper mulch, special care being taken to avoid touching the plants. Rogueing was effected previous to each cultivation and consisted in pulling up mosaic plants and removing them from the plot. Two types of topping were practised. In the one case all plants were topped consecutively in the row, while in the other all the healthy plants were topped first, leaving the mosaic plants to be done later. All transplanting was done by hand.

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Seed Bed

In Ontario and Quebec it is common practice, especially in the flue-cured districts, not only to maintain permanent glass-covered seed beds, but in addition to sterilize the soil each year, and to remove and destroy the refuse from a crop. These practices are undoubtedly responsible for the fact that seed beds in Ontario and Quebec are amazingly free from mosaic. For instance, in a survey of over 300 seed beds in the flue-cured area in Ontario during the past five years, only two seed beds showed any mosaic previous to pulling.

In the burley and cigar-leaf districts where sterilization of the seed bed soil is not practised so generally, mosaic was found occasionally, but even in these districts the percentage of infected beds was extremely low. The occasional contamination of seed beds with mosaic may be explained by lack of sanitary measures, by use of tobacco by workers, or by contamination from the soil during weeding. The relation of these factors to possible contamination in the seed bed was investigated and is reported in Table I.

TABLE 1.—INCIDENCE OF MOSAIC IN SEED BEDS TREATED IN VARIOUS WAYS AT ST. CATHARINES 1937 and 1938*

No.	Seed bed treatment	Amount of mosaic in seed bed at time of transplanting		Percentage mosaic in field
		1937	1938	1937
				%
1	Special precautions taken to prevent mosaic infection from outside; no smoking, and weeding done with hands washed with soap under running water.	No mosaic	No mosaic	1
2	No special precautions; weeding done by smoker whose hands were not washed.	Mosaic general	Mosaic general	70
3	Fine mosaic-powder dusted on uninjured seedlings except for injury resulting from weeding (clean hands).	Mosaic general	Mosaic general	28
4	Same as No. 3 except seedlings injured by brushing with clean hands.	Mosaic general	Mosaic general	48
5	Same as No. 3 except that seedlings were sprayed with a solution containing virus instead of dusted with mosaic-powder.	Mosaic general	Mosaic general	57
6	Same as No. 4 except that seedlings were sprayed with a mosaic-solution in place of mosaic dust.	Mosaic general	Mosaic general	56
7	†Mosaic trash incorporated in seed bed soil after it had been sterilized. No weeding and precaution taken to avoid contamination from outside.	7 plants‡	No mosaic	35
8	Same as No. 7 except that weeding was practised.	Mosaic general	Mosaic general	—

* Records taken when plants were ready for transplanting and in 1937 an additional record was taken of 200 plants from each seed bed which were transplanted to the field. Soil sterilized in all beds.

† In tests similar to No. 7 carried out for two years at L'Assomption in Quebec no mosaic occurred.

‡ These 7 plants may have become infected from some outside source, since in 3 of the 4 tests there was no mosaic.

In bed No. 1 where special precautions were taken to prevent contamination from outside sources, no mosaic whatever was present, whereas in bed No. 2 infection from outside sources was general. Moreover, beds No. 3, 4, 5, and 6 present additional evidence to the effect that if mosaic virus is introduced into a bed from any source, there is likely to be a high percentage of mosaic. A comparison of beds 1 to 6 with 7 and 8 indicates that seedlings contract mosaic from human agencies and certain cultural practices much more readily than they do from contaminated soil. Bed No. 7 indicates that the undisturbed seedlings did not "pick up" mosaic from the soil, whereas weeding (bed No. 8) was responsible for considerable infection.

SURVIVAL OF VIRUS IN THE SOIL

Relationship of Preceding Crops of Tobacco to Incidence of Mosaic

In the flue-cured districts of Ontario it has been observed repeatedly that crops heavily infected with mosaic have been associated invariably with land which had been cropped to tobacco the previous season. In fact, during the past seven years it has been observed each year not only that a considerably higher percentage of crops became infected with mosaic where tobacco followed tobacco in the rotation, but that in such cases there was also a much higher percentage of mosaic. In addition numerous cases have been encountered where seedlings from the same seed bed have been transplanted to new fields, or fields cropped to rye, and to fields cropped to tobacco the previous season with little or no mosaic showing up in the former, while a high percentage occurred in the latter fields. Since in each case both fields had been worked by the same men, and received the same treatment, it would seem logical to assume that the source of infection must have been by way of the soil. J. Johnson has reported similar observations in the following words: "Previously infected fields regularly develop a considerably higher percentage of mosaic than do newer fields".

In the cigar-leaf sections of Quebec, where tobacco is grown on a heavier type of soil, this association of incidence of mosaic with previous crops was not so apparent. In fact many fields have been observed where the percentage of mosaic was low (0.5 to 2%) following crops having as high as 40 to 50% mosaic. In other cases higher percentages of mosaic have been observed in crops on new land than in crops on soil that had grown 2, 3 or 4 successive tobacco crops, even though all fields may have been on the same farm and presumably received uniform treatment. On the other hand fields have been observed where high percentages of mosaic followed tobacco in the rotation. For instance, on one farm where tobacco followed tobacco, the crop showed 60% mosaic, whereas only 1.5% mosaic was present where seedlings from the same source had been planted in new soil. Nevertheless, the number of fields infected with mosaic in Quebec is small, and the percentage figures in such fields are low as compared with Ontario. This would suggest that overwintering of the mosaic virus is by no means as common in the cigar-leaf sections of Quebec as it is in the flue-cured districts in Ontario.

During the years 1935 to 1937 records of the incidence of mosaic were taken in plots at Delhi and St. Catharines where certain crop sequences were being followed.

TABLE 2.—SURVIVAL OF *Nicotiana virus I* FOLLOWING CERTAIN ROTATIONS

Plot no.	Location	Year	Percentage of mosaic	
			Tobacco following tobacco	Tobacco following rye or some crop other than tobacco
			%	%
1	Delhi	1935	29.0	1.0
2	Delhi	1936	19.0	6.0
3	Delhi	1936	14.0	4.0
4	Delhi	1936	45.0	4.0
5	Delhi	1936	10.0	3.0
6	Delhi	1936	17.0	0.0
7	Delhi	1937	43.0	0.5
8	St. Catharines	1936	17.0	2.0
9	St. Catharines	1937	3.0	0.0
10	St. Catharines	1937	3.0	2.0

A comparison of the above figures clearly indicates that a higher percentage of mosaic is always associated with a preceding crop of tobacco. This fact, along with the additional fact that all plots received the same cultural practices, suggests that the greater percentages of mosaic resulted from a higher initial infection, which in turn must have had its source in contaminated soil.

A further experiment relating to contaminated soil was conducted at St. Catharines in 1936 and is outlined in Table 3.

TABLE 3.—EFFECT OF CONTAMINATED SOIL ON INCIDENCE OF MOSAIC*

Plot no.	Plot history	Percentage mosaic 1936
		%
1	100% mosaic 1935; tobacco ploughed under in fall; healthy plants planted in spring 1936	17.0
2	100% mosaic 1935; tobacco pulled up in fall; healthy plants planted in spring 1936.	2.0
3	Healthy tobacco in soil that had not grown tobacco, tomatoes, cucumbers or peppers previously	0.0

* Plots cultivated; 150 plants from same source in each plot.

It is interesting to note that 17% mosaic occurred in the plot where tobacco followed tobacco, whereas no mosaic developed in the plot on new ground. This is, therefore, additional evidence that mosaic may overwinter in certain soils in Ontario and explains the fact that throughout the flue-cured district high percentages of mosaic are almost invariably associated with mosaic-contaminated soils. Moreover, the percentage of mosaic was reduced from 17 to 2.0% by removal from the soil of the mosaic plants, roots and all.

The relationship between virus-contaminated soil and incidence of disease in succeeding crops was studied under more controlled conditions in plots which were not cultivated, weeds being kept down by mulch paper or by hand. In 1939 at L'Assomption and Farnham in Quebec and at St. Catharines in Ontario tobacco was grown in special plots on soil that had produced a 100% mosaic crop (inoculated) and which had been ploughed under in the fall of 1938. At Farnham the weeds were kept down by mulch paper, whereas at L'Assomption and St. Catharines weeding was done carefully by hand.

TABLE 4.—EFFECT OF CONTAMINATED SOIL ON INCIDENCE OF MOSAIC*

Plot description	Percentage of mosaic						
	St. Catharines			Farnham		L'Assomption	
	1937	1938	1939	1938	1939	1938	1939
	%	%	%	%	%	%	%
Tobacco 100% mosaic; ploughed under and followed by healthy tobacco the next season.	3.5	2.5	9.0	2.0	1.5	0.5	1.0
Same source of healthy tobacco grown on soil that had not grown tobacco the previous year, or for several years	0.0	0.0	0.0	0.5	1.0	0.0	0.5

* Plots comprise 200 or more plants.

A study of Table 4 indicates (1) that though the mosaic virus overwintered readily in certain soils in Ontario, apparently it did not do so to any appreciable extent in the Quebec soils, and (2) that the percentage of mosaic contracted directly from the soil, while low in most cases, was enough to provide "infection centres". This would account for the high infection so often encountered when cultivation is practised, as can be gathered by reference to Tables 2 and 3.

Testing Contaminated Soils for Virus

Samples of soils from 100% mosaic plots were tested monthly for the presence of virus by inoculating *N. tabacum* variety Yellow Mammoth, and *N. glutinosa* with a water solution of the soil to be tested. These tests were carried out from October to June or July during 1936–37 and 1937–38. The virus was readily recovered in quantity, on the basis of number of lesions on *N. glutinosa*, each month from October to July inclusive, from flue-cured soils collected at Delhi and St. Catharines in Ontario. On the other hand, no virus was recovered from the cigar-leaf soils from Quebec after November in 1936 (L'Assomption only), and only a small amount up to May in 1938.

These direct soil tests indicate that in Ontario the mosaic virus overwintered readily and was therefore capable of infecting tobacco the following season, whereas in Quebec this was not the case in 1936–37, though possibly some infection of the 1938 crop may have occurred, since the virus was

recoverable as late as May in that season. In this connection it is interesting to note that during August, September and October the soil in Quebec was wet in 1936 and comparatively dry in 1937. Since moisture hastens decay of plant refuse, the difference in this respect in the two years probably accounts for the difference in survival of virus during the following winter.

Johnson (1) has added considerably to our knowledge of the effects of freezing, thawing, drying, moisture, etc., on the inactivation of tobacco mosaic virus, and it was considered desirable to check some of these points for our soils in Ontario. Accordingly, in the fall of 1936 and 1937 finely ground dry mosaic leaf tissue was added to clay and sandy soils respectively, in 5-inch pots, a number of which were kept dry, while others were kept moist under greenhouse conditions, while an additional number of each were placed out of doors, unprotected, to be subjected to natural weathering. In addition, an equal number of pots were treated with a solution containing macerated leaf tissue, filtered through ordinary coarse filter paper. Each month three samples of these various soils were tested for viability of the tobacco mosaic virus by directly rubbing leaves of *N. glutinosa* with a diluted soil solution.

TABLE 5.—EFFECT OF SOIL TYPE, MOISTURE, DROUGHT AND NATURAL WEATHERING ON INACTIVATION OF VIRUS IN POWDERED LEAF AND IN SOLUTION

Material	Number of months virus recoverable															
	Clay						Sand						Sandy loam			
	Dry		Moist		Outdoors		Dry		Moist		Outdoors		Dry		Moist	
	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938
Powdered leaf	12	7	8	6	6	6	11	10	5	2	5	5	11	—	9	—
Virus solution	2	2	5	4	2	—	2	1	3	4	1	—	2	—	5	—

Table 5 indicates that irrespective of soil type the virus, when added to the soil as a dried powder, remained active longer under dry than under moist conditions, though the reverse was true when the virus was added as a solution. Moreover, in each soil type the virus was inactivated much quicker under out-of-door than under greenhouse conditions with the possible exception of moist sand in 1938.

In this connection it should be pointed out that the mosaic leaf particles which were incorporated in the soils were about $\frac{1}{8}$ inch in size and accordingly would become decomposed much sooner than the larger pieces of tissue normally turned under by ploughing or discing. It is reasonable to assume that when the virus is inactivated in the small particles only after five to six months, it would require a much longer time to inactivate the virus in larger pieces of plant debris. Moreover, the evidence recorded in Table 5 suggests that even after the plant tissue has become disintegrated and the virus has gone into the soil solution, it may remain viable for at least another two months. The evidence from direct testing for presence of virus in soils of different types thus corroborates the field observations

that the virus is capable of overwintering in the soil under certain conditions.

Replacing Rogued Mosaic Plants

In the past it has been the practice of some growers to replace rogued mosaic plants with healthy plants, although it was realized that many such plants contracted mosaic. Hence tests were carried out to ascertain the percentage of such re-sets that might contract mosaic from the soil.

TABLE 6.—EFFECT OF REPLACING ROGUED MOSAIC PLANTS WITH HEALTHY PLANTS

Description of plots	Percentage mosaic							
	St. Catharines		L'Assomption		Farnham		Delhi	
	1937	1938	1937	1938	1937	1938	1935	1936
	%	%	%	%	%	%	%	%
Replacing 100 mosaic plants with 100 healthy plants	18	50	11	17	11	37	72	—*
Replacing 100 healthy plants with 100 healthy plants	0	7	0	0	1	5	4	—

* Transplants killed by drought.

These results indicate that tobacco plants planted in soil from which mosaic plants have been rogued will contract mosaic to a greater or less extent. During the four years this test was carried on, the lowest "pick up" of mosaic was 11% in 1937, while the greatest was 72% in 1935.

To obtain the effect of adding mosaic trash to the soil, in lieu of living mosaic plants, seedlings were planted in soil that had not grown tobacco for two years, and the same number of seedlings were planted in soil in which mosaic trash had been incorporated a short time previous to planting.

TABLE 7.—EFFECT OF PLANTING SEEDLINGS IN "MOSAIC" AND "HEALTHY" SOILS

Plot no.	No. of plants	Percentage mosaic			
		Delhi		L'Assomption	
		Mosaic soil	Healthy soil	Mosaic soil	Healthy soil
		%	%	%	%
1	200	55.0	0.0	50.0	0.0
2	200	30.0	0.5	44.0	2.0

Therefore, the results given in Tables 6 and 7 indicate that it is not safe to plant tobacco in soil in which mosaic plants have been growing, or in which mosaic trash is present.

TRANSPLANTING

Valleau and Johnson (4) and Lehman (2) have shown that the use of tobacco by the help during transplanting is a common and important means of spreading mosaic to the field. Observations and experimental tests carried out in Ontario and Quebec support their findings.

In the tests carried out in Ontario and Quebec it was the practice to plant 100 plants in a row for each treatment, and to take records of the incidence of mosaic 14 to 21 days later. A common source of virus material was used for all experiments in 1937 and 1938. Hands were washed with soap under running water in all cases except in one year at Farnham, when by mistake the hands were washed in a pail of water with the result that mosaic was spread promiscuously, as is shown in Table 8.

The results in Table 8 indicate that when the hands were contaminated with mosaic tobacco, mosaic was spread in transplanting to a greater or less extent. Even when manufactured cigarettes were smoked, infection as high as 6% was obtained. When the help "rolled their own" considerably higher percentages were obtained, indicating that the use of tobacco should be prohibited during transplanting.

It is particularly interesting to note that when the hands were washed *thoroughly* with soap under running water, they were freed from mosaic and little or no infection occurred. The use of tri-sodium phosphate for this same purpose gave fairly satisfactory results in three out of five trials. For some reason the results at Farnham in 1938 were not satisfactory.

The high percentage of infection (75%) that resulted from transplanting seedlings (190 healthy plus 10 mosaic), some of which were infected with mosaic, indicates clearly that a small percentage of mosaic plants in the seed bed may give rise to comparatively high infection in the field.

ROGUEING

Rogueing mosaic plants, especially previous to the early cultivations, is not practised as generally as it should be. The results given in Tables 9 and 10 demonstrate conclusively that rogueing is a very valuable aid in controlling mosaic, especially under conditions in Ontario.

TABLE 8.—EFFECT OF VARIOUS TRANSPLANTING TECHNIQUES ON SPREAD OF MOSAIC TO THE FIELD

Plot no.	Planted with hands	Percentage of mosaic 2 to 3 weeks after transplanting													
		Delhi		L'Assomption				Farnham			St. Catharines				
						1938			1938			1937		1938	
		1935	1936	1936	1937	a*	b*	1937	a	b	1936	a	b	a	b
		%	%	%	%	%	%	%	%	%	%	%	%	%	%
1	Cleansed by washing	5.5	6.6	0	—	—	—	—	—	—	0	0	0	—	—
2	After handling mosaic trash	80	100	41	42	47	15	3	87	73	52	61	87	27	14
3	As in No. 2, but thoroughly washed after handling mosaic trash	—	—	—	—	0	0	—	57*	19*	—	—	—	0	2
4	After smoking four cigarettes which were rolled with mosaic tobacco	30	—	22	10	4	16	5	11	33	—	61	88	7	7
5	After smoking manufactured cigarettes before planting each 25 plants	—	—	0	2	—	—	0	—	—	—	0	6	—	—
6	After smoking cigarettes manufactured with mosaic tobacco between each 25 plants	—	—	—	—	0	14	—	3	19	—	—	—	8	12
7	Dipped in solution containing mosaic virus	—	—	—	85	67	59	19	69	77	—	85	91	8	17
8	Same as No. 7 except washed thoroughly after being dipped in mosaic solution	—	—	—	1	5	8	0	13†	40†	—	2	23‡	0	4
9	Which transplanted a bundle of 200 plants containing 10 mosaic plants. All plants moist	—	—	—	—	82	85	—	51	58	—	—	—	33	30
10	Same as No. 9, but plants and hands dry	—	—	—	—	53	58	—	10	10	—	—	—	16	15
11	Which were dipped in mosaic solution and then washed thoroughly in a solution of tri-sodium phosphate and hands dried on clean towel	—	—	—	—	1	—	—	4	14	—	—	—	1	2

* a = transplanter a; b = transplanter b.
† By misunderstanding hands were washed in pail, rather than under running water.
‡ Apparently the hands were not cleaned thoroughly in this case.

TABLE 9.—EFFECT OF ROGUEING PREVIOUS TO CULTIVATION*

Location	Percentage of mosaic (not including inoculated plants)							
	Rogued				Not rogued			
	1935	1936	1937	1938	1935	1936	1937	1938
	%	%	%	%	%	%	%	%
Delhi, Ont.	2.0 0.0	4.0	–	–	16.0 13.0	40.0	–	–
L'Assomption, Que.	0.0	0.0	0.0	1.0	5.0	1.7	0.0	3.0
St. Catharines, Ont.	–	–	2.0 6.5†	0.2	–	–	13.0 29.5†	8.0
Farnham, Que.	–	–	1.0	9.0	–	–	0.0	12.0

* Plots contained 2% mosaic and comprised 400 plants; one-half rogued, while the other half was not.
† 10% mosaic at start.

In each year the value of rogueing in checking the spread of mosaic was demonstrated, though unsatisfactory results were obtained at Farnham in 1938.

TABLE 10.—EFFECT OF ROGUEING ON SPREAD OF MOSAIC FOLLOWING EACH OF THREE CULTIVATIONS*

Location	Percentage of mosaic (not including inoculated plants)					
	1st cultivation		2nd cultivation		3rd cultivation	
	Rogued	Not rogued	Rogued	Not rogued	Rogued	Not rogued
Delhi	4.0	40	10.0	66	19.9	94

* A plot of 400 plants containing 2% mosaic at beginning of experiment was used; plot was divided into two parts, one of which was rogued, whilst the other was not.

CULTIVATION

To ascertain the role of cultivation on spread of mosaic, field experiments were carried out over a 3-year period at different locations in Ontario and Quebec.

TABLE 11.—EFFECT OF THREE CULTIVATIONS ON SPREAD OF MOSAIC*

Location	Percentage of mosaic					
	Cultivated			Not cultivated		
	1936	1937	1938	1936	1937	1938
	%	%	%	%	%	%
St. Catharines	68.0	29.0	8.0	2.0	2.0	5.0
L'Assomption	–	–	30.0	–	–	6.0
Farnham	–	–	11.0	–	–	11.0

* Plots contained 200 plants (2% inoculated at beginning of season).
† In 1937 the plots contained 10% mosaic instead of 2% previous to cultivation.

The results given in Table 11 show that cultivation is an important factor in connection with spread of mosaic in the field, since mosaic infection was increased from 2% to as much as 68% by cultivation. Having in mind that a small percentage (1% to 3%, Table 4) of mosaic may be contracted directly from contaminated soil, it is apparent that in such cases cultivation may be responsible for a considerable spread of mosaic from the initial infection.

To ascertain the effect of cultivating implements in spreading mosaic from an infected area to a healthy area, or from an infected field to a healthy field, plots were set up in such a manner that cultivation took place from each of 4 rows of 50 mosaic plants, directly to each of 4 rows of 50 healthy plants.

TABLE 12.—EFFECT OF CULTIVATING FROM 100% MOSAIC ROWS INTO ROWS OF HEALTHY TOBACCO PLANTS

Location	Percentage of mosaic plants in healthy(?) rows		
	1936	1937	1938
	%	%	%
St. Catharines	—	75.0	10.0
Farnham	—	22.0	26.0
L'Assomption	13.3	1.0	44.7
Delhi	53.0	—	—

In connection with the above results it is of special interest to note these further details in connection with plots at St. Catharines. In 1937 the first two cultivations from mosaic to healthy rows were effected under dry conditions and resulted in only 4% spread of mosaic to the healthy rows. The next two cultivations were carried out while the plants were heavy with dew and increased the percentage of mosaic to 75%.

To ascertain the effect on spread of mosaic where cultivation was effected under dry as compared with wet conditions, plots were set up in which half was cultivated only when the sun was shining and the plants were dry, whilst the other half was cultivated when the plants were wet with dew or rain.

TABLE 13.—EFFECT OF THREE CULTIVATIONS UNDER DRY AS COMPARED WITH MOIST CONDITIONS*

Location	Percentage of mosaic					
	Cultivated					
	Dry			Wet		
	1937	1938		1937	1938	
St. Catharines	2.0	8.0	†10.0	30.0	26.0	*29.0
Farnham	–	–	26.0	–	–	41.0
L'Assomption	–	3.0	44.0	–	45.0	55.0

* Plots cultivated four times, and 2% of the plants inoculated at beginning of the season.

† In 1938 an additional test was effected by cultivating from 100% mosaic rows directly into rows which contained healthy plants at the beginning of the experiment.

The data presented in Tables 9, 12, and 13 prove conclusively that considerable mosaic may be spread during cultivation, and that this is especially true if the plants are wet with dew or rain.

TOPPING

It is well recognized that considerable mosaic may be spread during topping if care is not taken to prevent it. Accordingly, in 1937 and 1938, to obtain information on this point, plots were set out in which 3% of the plants, equally distributed, were inoculated with mosaic 14 to 15 days before topping.

TABLE 14.—INCIDENCE OF MOSAIC AFTER 15 DAYS, INDUCED BY TWO METHODS OF TOPPING

Topping methods	No. of plants	Percentage of mosaic								
		St. Catharines			Farnham		L'Assomption			Delhi.
		1936	1937	1938	1937	1938	1936	1937	1938	1936
		%	%	%	%	%	%	%	%	%
1. All healthy plants topped first	200	36	3	12	8	7	0	—*	0	13
2. Plants topped consecutively in the rows	200	78	45	30	14	43	0	—	7	34

* Results were not available at L'Assomption due to loss of plants by hail.

DISCUSSION

From the evidence submitted the important primary sources of infection are contaminated soils, and the use of tobacco while transplanting or otherwise working with the growing crop. Where permanent seed beds are maintained, and the soil is sterilized annually, there is little chance for the seed bed becoming an important source of primary infection unless, of course, it becomes contaminated from some outside source. Johnson (1) and Mulvani (3) have demonstrated that tobacco becomes infected by way of wounds on leaf or stem tissue, and rarely, if ever, through roots. The fact that in five out of six seed beds no mosaic was "picked up" from contaminated soil when the seedlings were undisturbed, whereas the incidence was high when weeding was practised, since in this process infection was facilitated by bringing contamination from soil or hands into contact with leaf or stem tissue, supports their findings.

That contaminated soil may be an important source of primary infection, has been demonstrated by field surveys, by experimental field tests, and by testing for viable virus in overwintered contaminated soils. In Ontario the consistent association of high percentages of mosaic with preceding crops of tobacco is to be explained by direct infection from the soil, which need not be extensive, and a greater spread by cultivation from such initial infection centres. That this same association does not hold consistently for mosaic in the cigar-leaf sections of Quebec has been shown to be due to the inactivation of the virus previous to the next planting

season. Why virulence is lost in the one case and not in the other requires further investigation. In this connection it is interesting to note that the results obtained under Ontario conditions are in agreement with Johnson (1) who concludes "that the soil is a very common source of primary infection", and Lehman (2) who has presented evidence to the effect that though a low percentage of plants may be infected directly from the soil, the bulk of the spread in the field results from cultivation and certain cultural practices. That the amount of contaminating material is an important factor in connection with overwintering of tobacco mosaic virus, was demonstrated by a reduction in mosaic from 17 to 2% when mosaic plants were removed from the soil in the fall instead of being ploughed under (Table 3); Lehman (2, p. 24) and Wolf (5, p. 160) have reported similar findings.

Another common agency whereby mosaic may be introduced into the field is the smoking or chewing of tobacco by the workers whilst working with the growing crop. This is particularly true at transplanting, as is demonstrated by the results given in Table 8. Though the tobacco used in these tests, with one exception (plot 5), was known to contain virus, thus accounting for the high percentage of mosaic obtained, nevertheless these results indicate that mosaic may be spread to the field if the help use tobacco in any form. Even when manufactured cigarettes were used, infection as high as 6% was obtained. That the commercial brands of cigarettes and pipe tobaccos may be a source of infection is shown by the fact that viable virus was obtained from five of six common brands tested. Moreover, of eight samples of mosaic tobacco leaf that had gone through the kiln in the usual manner seven still contained viable virus, indicating that the kiln does not usually inactivate the virus. That it is equally important to avoid using tobacco during topping, is shown by the following interesting case. In Quebec in 1938 two brothers who do not use tobacco in any form had produced a crop free from mosaic up till topping time, when the help of a neighbour was secured. Two weeks after topping it was noted that considerable mosaic was present in the part of the field topped by their neighbour, though the section of the field topped by the brothers was still healthy. The neighbour was a smoker and his contaminated hands had apparently spread the mosaic.

The value of rogueing previous to cultivating is well established. Lehman (2), Wolf (5), Valleau and Johnson (4), and others have stressed the importance of rogueing in control of mosaic. The results given in Tables 9 and 10 support their findings. It would appear that rogueing would be of particular value wherever direct infection from the soil is probable, as for instance, where tobacco follows tobacco in the rotation.

Lehman (2) and others have demonstrated that considerable mosaic may be spread in cultivating and topping. These agencies were tested in Ontario and Quebec and it was found that when rogueing was not practised, cultivation was responsible for heavy spread, while spread was reduced greatly where rogueing was effected. It was also demonstrated that higher percentages of mosaic were spread by cultivation under wet as compared with dry conditions, a fact of considerable practical importance. In connection with topping it was shown that indiscriminate topping of healthy and mosaic plants resulted in extensive infection, while spread was reduced

greatly by the simple expedient of topping all healthy plants first, leaving the mosaic plants till later.

CONCLUSION

It may be concluded that: (1) it is essential to use sterilized soil in the seed bed and to take whatever precautions may be necessary to eliminate the possibility of infection from outside sources such as contaminated hands, seed, clothing, tools, boards and canvas or tobacco trash; (2) tobacco should be rotated with some other crop, such as rye; (3) the help should not be allowed to use tobacco in any form while they are working with seedlings, transplants or plants in the field; (4) the hands should always be washed with soap under running water before working with tobacco; and (5) it is essential to *(a)* rogue mosaic plants before each cultivation, *(b)* cultivate under dry conditions in so far as possible and *(c)* top and sucker healthy plants first, leaving all mosaic plants till later.

SUMMARY

1. The seed bed may be an important source of primary infection in the field, unless certain precautionary measures are taken.

2. It has been shown that the virus of tobacco mosaic is capable of overwintering in the soil, thus necessitating the rotation of tobacco to avoid primary infection from the soil.

3. Evidence has been given which shows that mosaic may be spread readily during transplanting, especially if the help use tobacco in any form.

4. Rogueing has been demonstrated to be of material aid in checking the spread of mosaic under field conditions.

5. Cultivation is one of the most important agencies whereby mosaic may be spread in the field.

6. In topping a field of tobacco in which mosaic is present it is advisable to top all healthy plants first, leaving the mosaic plants till later.

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The author is pleased to acknowledge his indebtedness to the staffs of the Experimental Farms at Delhi, Ont., and L'Assomption and Farnham, Quebec, especially Messrs. F. Stinson, G. Turcotte and R. Bordeleau, who took the records and supervised the plots at their respective stations. The author is also indebted to Mr. H. Phillips and Mr. G. O. Madden at the St. Catharines laboratory, who assisted with the taking of records, making inoculations and growing of the large number of plants used in the experiments.

REFERENCES

1. Johnson, James. Factors relating to the control of ordinary tobacco mosaic. Journ. Agr. Res. Vol. 54 : 239-271. 1937.

2. Lehman, S. G. Contaminated soil and Cultural Practices as related to occurrence and spread of tobacco mosaic. Tech. Bull. 46. North Caroline Agr. Exp. Sta. 1934.

3. Mulvani, M. Root inoculations with the virus of tobacco mosaic. Journ. Bact. 19. 1930.

4. Valleau, W. D. and E. M. Johnson. Tobacco mosaic. Sources of infection and control. Bull. 376. Ken. Agr. Exp. Sta. 1937.

5. Wolf, F. A. Tobacco diseases and decays (Text book). Durham, N.C. 1935.

THE EFFICACY OF COBALTIZED SALT FOR THE PREVENTION OF COBALT DEFICIENCY SYMPTOMS IN SHEEP[1]

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The efficacy of cobalt chloride fed in solution to sheep on a cobalt deficient dry ration in preventing or curing a condition of cobalt deficiency was reported in a recent paper by the writers (1). Investigators in New Zealand (2) have shown that the use of a cobaltized salt lick prevents the development of deficiency symptoms in areas where the soil and pasturage are low in cobalt. Conditions in western Canada as applied to farm flock management differ from those in New Zealand in that the pasture period is relatively short, resulting in a prolonged period of grain and hay feeding. Some of the hay and grains commonly used in sheep rations have been found to be low in cobalt. The possibility of utilizing a cobaltized salt lick as a means of supplying cobalt to ewes on such a cobalt deficient dry ration under barn conditions was the subject for study in the feeding trials being reported.

EXPERIMENTAL PROCEDURE

The 2-year-old range ewes used in this study were selected from two sources. Fourteen of the ewes had received a cobalt-chloride solution for approximately 20 months prior to the start of this trial and were normal in thrift and in a good condition of flesh. Ten ewes had been kept on a cobalt deficient ration for about 18 months. These ewes developed pronounced deficiency symptoms but during a subsequent 2-months' period of cobalt feeding they made rapid gains in weight and recovered a condition of normal thrift. In spite of the improvement in condition, however, these particular ewes still weighed an average of 14 pounds less than those in the first group. The two groups of 14 and 10 ewes, respectively, were divided so as to constitute two experimental lots of 12 sheep. On this basis of allotment, each group contained 7 ewes that had been receiving cobalt for an extended period and 5 ewes that had received cobalt for only two months following the development of cobalt deficiency symptoms.

The ewes in Lot I received 3 ounces of a solution containing 4 mgms. of cobalt twice weekly, while the ewes in Lot II were fed a salt mixture containing 4 ounces of cobalt-chloride in a ton.[5] The basal ration for both lots consisted of timothy and oat (greenfeed) hay, oats, iodized salt and mono-calcium phosphate. Both groups were maintained under similar environmental and management conditions.

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[1] Contribution from the Department of Animal Husbandry, University of Alberta, Edmonton—with financial assistance from the Experimental Farms and the Science Services, Dominion Department of Agriculture, Ottawa, Canada.

[2] Associate Professor of Animal Husbandry.

[3] Professor of Animal Husbandry.

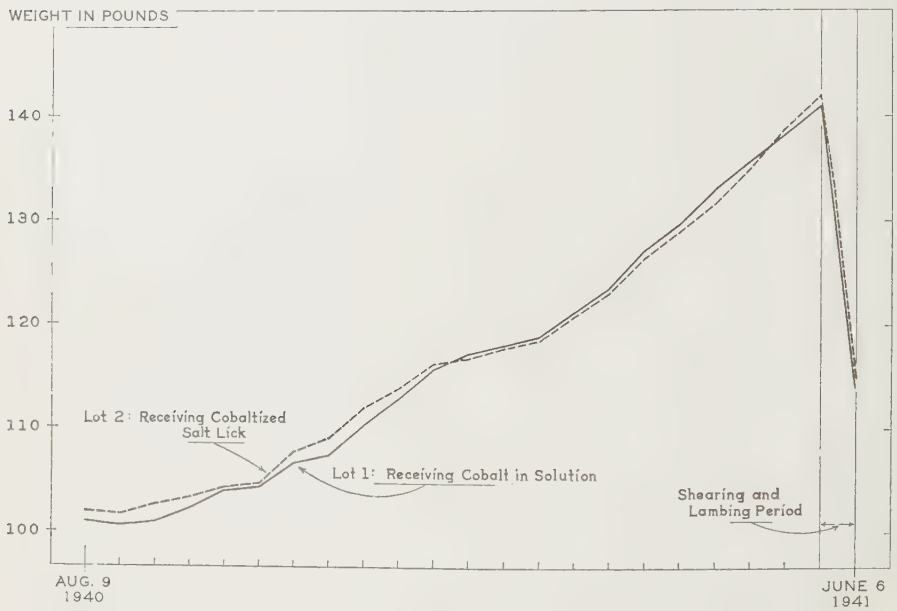
[4] Professor of Animal Husbandry.

[5] Recommended by New Zealand authorities for use in the "bush sick" areas of New Zealand.

The experiment was conducted from August 9, 1940, to June 6, 1941, a period of sufficient length to study the effect of the two treatments on body maintenance, wool growth, and reproduction.

RESULTS

During the 300-day experimental period each ewe in Lot I received a total of approximately 344 mgms. cobalt, in the solution of cobalt chloride fed twice weekly. The ewes in Lot II consumed a total of 187.5 pounds of salt mixture which contained approximately 2633 mgms. of cobalt. Each ewe in Lot II, therefore, received only 219 mgms. of cobalt or 64% of the amount fed to Lot I. The amounts of hay, grain, and salt fed to both lots were the same.



Body Maintenance

Both groups of ewes increased in weight at approximately the same rate, as is shown in Figure 1. At no time during the trial did the average weight of the ewes in the two lots differ more than $1\frac{2}{3}$ pounds. The ewes receiving the cobaltized salt averaged 1 pound heavier at the start of the trial and were likewise 1 pound heavier following lambing. At this time all of the ewes were in a normal thrift, thus indicating that the two methods of feeding cobalt were equally satisfactory from the standpoint of body maintenance.

Reproduction

All ewes conceived normally and gave birth to lambs. Table 1 shows that there were three sets of twins in Lot I receiving their cobalt in the drench. The larger number of twins born in Lot I resulted in a lower average birth weight for that lot.

TABLE 1.—REPRODUCTION DATA

	Lot I Cobalt in solution	Lot II Cobaltized salt
No. of ewes in lot	12	12
No. of ewes lambed	12	12
No of lambs born	15	13
Vitality of lambs at birth:		
% strong	93	92
% weak	7	0
% dead	0	8
Average weight of lambs at birth	8.7 lb.	9.8 lb.

Since there was only one lamb in each lot not classified as "strong" at birth, there does not appear to be any significant difference in reproduction that may be attributed to a difference in the method of feeding cobalt.

Fleece Weights

The average weight of the sheared fleeces from the ewes of both lots differed by only .1 pound. The average weight of the fleeces from the ewes receiving cobalt in solution was 8.55 pounds, and from those receiving cobaltized salt, 8.45 pounds. There was no apparent difference in the condition of the fleeces from the two groups at the time of shearing.

CONCLUSIONS

The fact that there were no significant differences in average growth, reproduction, and fleece weights between the two groups, showed that the feeding of cobaltized salt was as satisfactory as the feeding of cobalt chloride in solution to thrifty sheep on a low cobalt ration.

Under the conditions of the trial the use of a cobaltized salt mixture containing 4 ounces of cobalt chloride per ton of salt provided 64% as much cobalt as when 8 mgms. of cobalt in solution was fed weekly. This lower cobalt intake was sufficient to maintain the ewes in as satisfactory a condition as when larger amounts were administered in solution.

REFERENCES

1. BOWSTEAD, J. E., J. P. SACKVILLE, and R. D. SINCLAIR. The development of cobalt deficiency in sheep. Sci. Ag. 22 : 314-325. 1942.

2. DIXON, J. K. The use of a cobaltized salt lick in the control of a lamb ailment at Morton Mains, Southland. New Zealand Journ. of Sci. and Tech. XVIII : 12; 892-897. 1937.

THE RELATIVE EFFECT OF ENVIRONMENT AND HEREDITY UPON BODY MEASUREMENTS AND PRODUCTION CHARACTERISTICS IN POULTRY[1]

II. PERIOD OF EGG PRODUCTION

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In continuation of research previously reported (3) concerning the effect of environment and heredity upon body measurements of cockerels during the period of growth, an analysis of data obtained from the pullets of the same stock was made covering the period of egg production. In the communication referred to above, the theoretical basis for and the objects of the whole investigation were set forth in detail and need to be referred to only very briefly in this paper. Fundamentally, the effect of environmental as opposed to genetic factors in determining the course of such characters as growth and egg production is not clear in most experimental data because of the very great difficulty in holding constant either one or the other of these factors. Under practical conditions of poultry husbandry the difficulty in appraising the relative effect of these factors becomes so great as to make other than a rough estimate impossible; hence, in the past, improvements in egg production, for example, have been largely credited to heredity where obviously environment may have shared an equal if not greater responsibility. Some of the most convincing research along this line with poultry (8), (9), (10), (11) seems to indicate that failure to appreciate the great importance of environment in production has without doubt led to over emphasis upon breeding as an efficient and practical means of producing desired results. Similar findings for pigs (2) and cattle (12) also add strength to the above contentions. The experiment reported herein was planned to obtain through adequate control of environment and heredity, an approximate measure at least, of their relative effect upon egg production, egg weight, days to first egg, body weight at first egg, and maximum body weight.

MATERIALS AND METHODS

As stated in greater detail in a previous paper (3), an exchange of hatching eggs between three flocks was made in such a way that each of the strains was represented at each of three environments thus making differences between strains at any one environment due to hereditary factors, while those between the same strains at the different locations would be due to location or environmental causes. The pullets were raised to maturity under the same conditions for each strain at each environment, the chicks of all strains being reared together in the same brooder houses. Upon reaching sexual maturity they were again intermingled in the same

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pens of the laying houses. As in the previous publication the same strains and locations were designated as A, B, and C.

Egg production was taken as from time of first egg to September 4 of the following year, the production of the birds which lived through the test only being considered. All birds were trap nested. Since four different hatching dates were involved, the cutting off of production at September 4 may be considered to have reduced the production period in the case of the late hatched birds thus creating a bias in favour of early hatched or early developing birds although this effect would be similar for all groups. For this reason expected annual production was calculated on the basis used in progeny testing at this institution. An analysis of data from 2,017 unculled pullets to determine the number of eggs laid after September 4 by birds coming into production at various starting dates was carried out by Bird and Sinclair (1). From these data a table was set up indicating the number of eggs which should be added, on the average, to the September 4 production in order to complete the biological laying year. As a check upon this method a random sample of birds approximating the size of the smallest sample in this experiment (35) was taken, and the expected annual production calculated on the basis above mentioned. This group ranged from September 18 to December 29 in date of first egg, with a production to September 4 of 159 to 236 eggs per bird and an annual production ranging from 175 to 253 eggs. The actual average annual production per bird was 215.7 ± 3.17 eggs, and the calculated expected annual production 215.3 ± 3.29 eggs, showing a negligible error and a low variability of calculated from actual within the sample. Both production to September 4 and calculated annual production are therefore shown herein.

Egg weight was taken for each individual bird, the eggs being weighed for one week in each four weeks throughout the laying period and the mean of these weights taken as the average weight for the bird. Days to first egg constituted the number of days between date of hatch and date of first egg.

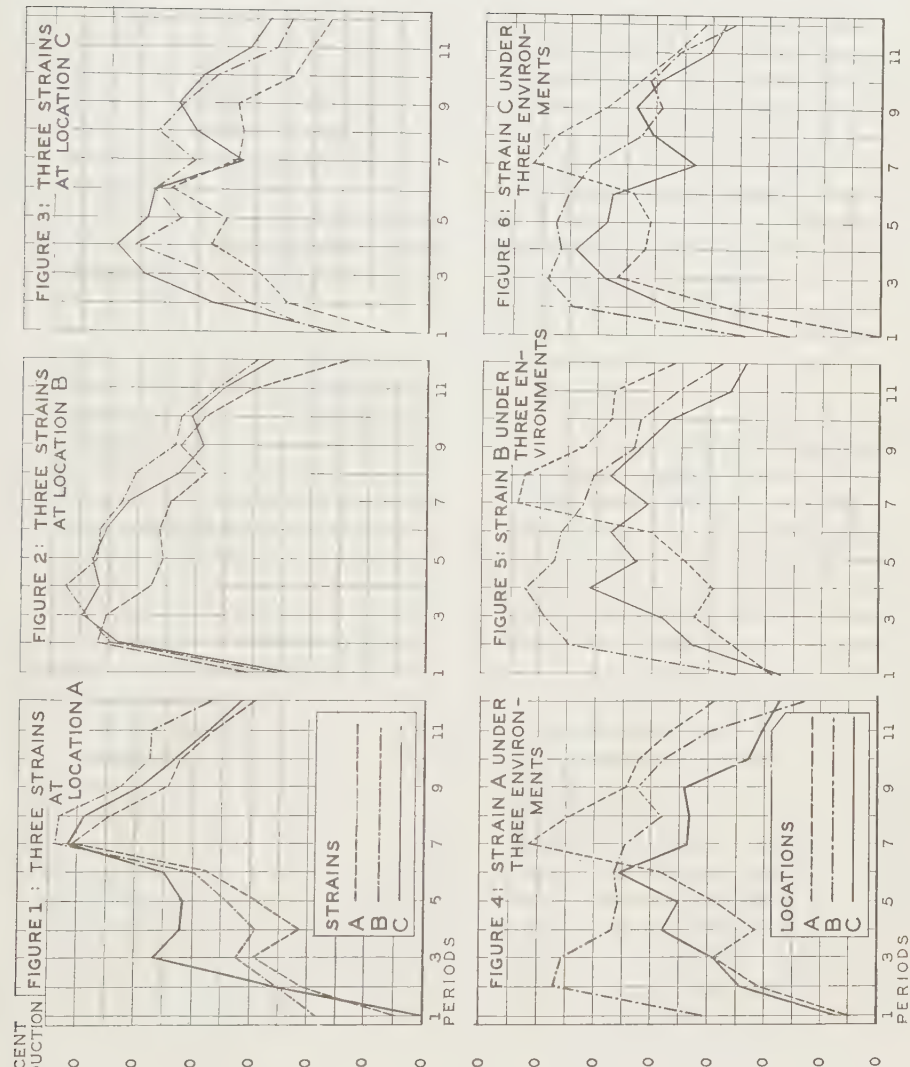
Body weight at first egg was the weight of each bird taken immediately after laying of the first egg. Body weight was taken every four weeks throughout the period of production, the greatest weight being used as maximum body weight.

RESULTS

The experiment progressed satisfactorily with one exception, namely, that an unduly high mortality was experienced for strains B and C at locations A and B as seen in Table 1. It became necessary therefore to determine whether the production of the birds which lived through the test was an adequate sample of the production of the original population. It could be argued that the birds which died might have been individuals of lower productive capacity than those which lived, in which case the average production of the groups having the highest mortality would be unduly high and poorly represent the original sample. Or, conversely, it might be claimed that high mortality might be associated with high morbidity in the birds which survived thus depressing their production.

TABLE 1.—MEAN VALUES FOR PRODUCTION CHARACTERISTICS FOR STRAINS AND ENVIRONMENT

Origin	Prod. to Sept. 4			Annual prod.			Egg weight			Days to first egg			Body weight at 1st Egg			Body weight—maximum			Percentage mortality		
	Location			Location			Location			Location			Location			Location			Location		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Strain A	185.99	211.05	170.06	203.24	220.03	185.76	57.31	54.69	55.82	191.14	163.08	185.24	5.95	5.52	5.78	7.52	7.09	7.00	23.33	57.30	68.81
Strain B	209.72	236.21	198.88	227.52	247.15	215.98	56.90	55.05	55.25	195.44	170.75	191.00	5.82	5.38	5.51	6.91	6.63	6.61	16.47	36.84	40.82
Strain C	204.80	222.41	199.93	225.27	235.18	217.74	58.58	57.36	59.23	204.86	175.19	195.13	6.01	5.79	5.95	7.55	7.49	7.13	17.35	29.06	29.66



FIGURES 1 to 6. Percentage of egg production for twelve 28-day periods showing strain and environmental differences.

Harris (4, 5) published data indicating that birds which died during the laying year were lower producers previous to death than those which survived. Hays and Sanborn (6) on the other hand, found that, in their strain of Rhode Island Reds, the winter production of birds dying after March 1 was no less than that of birds which survived the laying year. Munro (7) came to the conclusion from an analysis of data from Canadian Egg Laying Contests that birds which died were on the average poorer layers than those which survived.

In view of this conflict of opinion it was decided to explore further sources of information on this subject and particularly to determine if possible whether in this instance the production of the surviving birds was a good sample of the production of the whole group prior to the heavy mortality.

For this purpose progeny test data from 12 Experimental Farms over a period of five years was analysed statistically. After the removal of the effect of years and locations the data showed correlations between percentage mortality and production level of $r = -0.2527 \pm 0.1395$ to $r = -0.3372 \pm 0.1437$ based on upwards of 40 degrees of freedom in each instance. Since these correlations represent the appropriate measure of the uncomplicated relationship between mortality and production it may be considered that over a period of years and a wide range of strains and environments the relationship between mortality and production level is of questionable significance and so low as to be of little practical effect. It may be presumed therefore that production of surviving birds would be a reasonably good expression of the inherent productive ability of the whole group. With certain disease conditions this might not hold, but over a wide range of causes of mortality as represented in these data, this is the case.

To confirm these observations further, the chi-square test for goodness of fit was used to determine whether the surviving birds were a good sample of the original population, by comparing the distribution of their egg production to September 4 with that of the whole group at the end of 112 days and 224 days of production. The odds that the surviving birds were not a good sample of the groups at 112 and 224 days were only 2.5 : 1 and 1.3 : 1 respectively, and it may therefore be presumed that the use of the production of the surviving birds to represent the original group would be justified. Since this calculation was made for the group suffering the highest mortality viz. 68.8% it was felt that this procedure could be applied to all groups. It was also deemed that other characters such as egg size and body weight should be considered upon the same basis.

Table 2 shows the variance analysis for the characters concerned, the necessary adjustments having been made because of unequal numbers in the subclasses (Yates (13)).

Egg Production

A consideration of the mean production to September 4 and for the laying year shows significant effects of both strain and environment. The differences due to environment besides being more consistent are significantly greater than those due to strain. It would seem that strain A was of lower productive potentialities than strains B and C and environment B more favourable for the attainment of high production. By far the greatest

production levels ranging up to 21% higher than certain competing groups were made under this latter environment. Strain A, while much lower than the other strains in production gave a good account of itself under the influence of environment B.

The differences in egg production are graphically portrayed in Figures 1 to 6. In these charts percentage production for 12 periods of 28 days each is set forth in such a way that in Figures 1 to 3 the spread of the curves indicates the extent of the differences due to strain or heredity while in Figures 4 to 6 the degree of spread of the curves indicates the effect of environment. Not only is it evident that the spread is much greater for environment, but each curve has its own distinct pattern showing the overbearing effect of the environments upon the course of production during the year. Not only does environment produce greater differences in average annual production therefore, but it would seem to have an even more marked effect upon fluctuations which determine the course of production at different periods during the laying year.

Egg Weight

Significant differences in egg weight existed both between different strains and different environments. The differences due to heredity on the average however, were not significantly greater than those due to environment, although in many individual instances this was the case. It should be noted that egg weights at location B were consistently and significantly lower than at either of the other locations.

Days to First Egg

Some of the outstanding differences which occurred were in this character. Regardless of strain, sexual maturity was reached under the environment of location B 20 days earlier on the average than at the next earliest location. This effect very much outweighs that of heredity since strain differences are small, although consistent.

Body Weight at First Egg

While some significant differences occurred because of both environment and heredity these seem to have had a similar effect upon body weight at sexual maturity on the average. Again, the greatest and most consistent differences occurred between environment B and those at the other locations.

Maximum Body Weight

The situation with regard to maximum body weight is that the apparent environmental effect at location B for body weight at first egg has been replaced by a strain effect for maximum body weight particularly evidenced by a low weight for strain B. As a result the differences due to heredity significantly outweigh those due to environment for this character.

Mortality

The effect of environment and heredity are difficult to assay. From the data available, however, it would seem that both have a direct influence upon the course of mortality since at location A mortality is remarkably

low regardless of strain whereas this is also the case for strain C regardless of environment. It does seem however that environments B and C had a definitely adverse effect upon livability, although strain C was definitely more resistant to the various diseases which brought about death.

DISCUSSION

As in the previous paper of this series, through the interchange of stock of different strains a high degree of control was obtained over both environment and heredity so that the relative effects of each upon any character might be measured.

The results of this test indicate quite clearly that environment had a much greater effect than heredity in determining the course of egg production under the conditions of this test. It is only reasonable to believe, therefore, that the improvement of environment would be a much more effective instrument in increasing production than would an attempted

Table 2.—Analysis of variance of egg production characters

	Between locations. Mean square (D/F = 2)	Between origins. Mean square (D/F = 2)	Inter-action. Mean square (D/F = 4)	Within classes. Mean square (D/F = 562)
Production to Sept. 4	43,788.01*	28,162.34*	1460.00	1734.46
Egg weight	168.26*	212.12*	30.48	14.90
Days to first egg	35,015.16*	3,708.62*	151.25	915.11
Body weight at first egg	4.88*	5.12*	0.51	0.49
Body weight-maximum	3.56*	23.73*	3.38**	0.63

* Significant at 1% point.

improvement by breeding methods. The fact that an increase in egg production of 41, 37 and 22 eggs per bird to September 4 and of 34, 32, and 17 eggs per bird for the year was brought about by placing each of three strains under a more favourable environment is excellent evidence for the statement just made. Had great extremes of environment been used much larger differences might have been anticipated. In actual fact however, each environment was typical of good commercial practice in this country, most of the environmental differences apart from climate being apparently of so minor a nature that they were far from obvious. For example, well balanced rations of similar formulae, and laying houses of the same general type and construction were common to all environments. Climatically the obvious differences were between moderately cold, humid winters with cool summers at location A, relatively mild winters with warm summers at location B, and cold winters with very warm summers at location C. These descriptions may be further clarified by the mean and maximum range in temperatures for the period of the experiment as follows:—location A, 40.8° F.: −12° F. to 84° F.; location B, 47.8° F.: −2° F. to 91° F.; location C, 40.2° F.: −34° F. to 93° F. It should be pointed out that even these climatic differences were greatly reduced by the fact

that excellent housing accommodation was used under all three climates and that through adjustment of ventilation and the closing of windows actual temperature differences within the pens from location to location would be much smaller in winter for example since the maximum precautions against cold would be taken in the most severe climate. Actually the flock at the Dominion Experimental Farm which is subject to the lowest temperatures of any such farm in Canada, invariably has at least average and usually better than average high production. The scope of the production differences shown in these data brought about by moderately small environmental differences together with the limited effect of strain lends weight to the argument of Munro (9) that "The increase which has occurred in the production of the average Canadian hen since trap-nesting and individual pedigreeing became widespread is mostly due to improvements in feeding and management (environment) and that the amount of this increase which is the result of breeding work is far smaller than is commonly supposed".

One of the most outstanding results of these tests is embodied in the data covering days to first egg. The lower number of days to first egg indicated by differences of 28 days, 24 days and 29 days in the case of environment B as against A, for example, indicates a marked effect upon this very important character. In this instance climatic differences between the two environments concerned were even less marked than was the case for egg production since summer temperature which does not differ to nearly so great an extent between the environments concerned as winter temperature is the one concerned with the rearing period to time of first egg. Since the highly significant simple and partial correlations for days to first egg and egg production were $r = -0.2119$ and $r = -0.2413$ in these data it is evident that the number of days to first egg had a moderate effect upon egg production and that one of the important effects of environment was its ability to speed up or retard the onset of sexual maturity thus affecting both economy of rearing, and egg production. It should also be noted in this connection that both egg weight and body weight at first egg are slightly lower for the environment causing the earliest sexual maturity.

Maximum body weight was affected to a greater extent by heredity than environment. This would bear out the apparent tendency reported in the previous paper of this series (3) namely that in the cockerels, regardless of differences brought about by environment during the period of rapid growth, the tendency existed for birds to attain eventually their inherited body size.

It should be noted that diseases which are passed down through the egg, if present, will show up in these data as strain or hereditary effects whereas they are not actually inherited but are passed down mechanically to the progeny through the egg. One of the diseases present in all groups of these birds was leucosis. Evidence is gradually accumulating to indicate this mode of transmission to be the fact for this disease. To the extent that this disease does influence the results in this project the importance of heredity will be exaggerated since the effect will appear in that portion of the data representing heredity.

The data from this experiment, therefore, may be considered to bear out information already reported for the growth period namely, that environment has a considerably more potent effect upon production characteristics than heredity. The exception to this statement as indicated by these data would be egg weight which appears to be affected similarly by both factors and maximum body weight which apparently is affected by heredity to a greater extent than the other characteristics studied.

SUMMARY

Through an experiment embodying control of environmental and hereditary factors the relative effect of each upon production characteristics in laying pullets was estimated with the following results.

1. Egg production to September 4 and for the calculated laying year was influenced by environment to a much greater degree than by heredity. Since this was the case even though the actual environments compared in this experiment differed to only a moderate degree, the importance of improvement of environment as an instrument in increasing egg production is emphasized by these results.

2. Days to first egg was also affected by environment to a very great degree and by heredity only to a limited extent. The economic importance of early sexual maturity adds weight to the value of this finding.

3. Body weight at first egg was affected directly by both environment and heredity and to a similar degree.

4. Egg weight and maximum body weight were affected by both factors. Heredity, however, was the most potent factor in governing maximum body weight.

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REFERENCES

1. Bird, S. and J. W. Sinclair. Unpublished data 1936.

2. Bywaters, J. H. The hereditary and environmental portions of the variance in weaning weights of Poland China pigs. Genetics, 22 : 459. 1937.

3. Gutteridge, H. S. and J. B. O'Neil. The relative effect of environment and heredity upon body measurements and production characteristics in poultry. I. Period of growth. Sci. Agric. 22 : 378-389. 1942.

4. Harris, J. Arthur. Poultry Sci. 6 : 1. 1926.

REFERENCES—Concluded

5. HARRIS, J. ARTHUR. Poultry Sci. 7 : 215. 1927.

6. HAYS, F. A. and SANBORN, RUBY. Bull. Mass. Agric. Exp. Sta. No. 242. 1928.

7. MUNRO, S.S. The relation of production to mortality in the domestic fowl. J. of Agric. Sci. 26 : 1. 1936.

8. MUNRO, S. S. The inheritance of egg production in the domestic fowl. I. General considerations. Sci. Agric. 16 : 591. 1936.

9. MUNRO, S. S. Inheritance of egg production in the domestic fowl. II. Increases in production, their extent and characteristics with a discussion of causal factors. Sci. Agric. 17 : 376. 1937.

10. MUNRO, S. S., S. Bird and J. W. HOPKINS. Inheritance of egg production in the domestic fowl. III. Differences in transmitting ability of dams and the degree of dam-daughter correlation. Sci. Agric. 17 : 386. 1937.

11. PETROV, S. G. Analysis of the development of high and low lines of Leghorns at Cornell. Poultry Sci. 14 : 6. 330. 1935.

12. PLUM, MOGENS. Causes of differences in butterfat production of cows in Iowa Cow Testing Associations. J. Dairy Science 18 : 12, 811. 1935.

13. YATES, F. The analysis of multiple classifications with unequal numbers in the different classes. J. Am. Stat. Assn. 29 : 51. 1934.

SOME OBSERVATIONS ON THE TOLERANCE OF SALINITY BY CEREAL CROPS IN SASKATCHEWAN[1]

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INTRODUCTION

As in other areas of similar climate, salinity, or an excess of readily soluble salts in the soil, is a serious hindrance to the development and utilization of certain agricultural lands in Western Canada. Although an abundant international literature on this subject exists, publications relating to specific Canadian problems are few. Early work by the late Dr. Shutt and his associates, published between 1918 and 1923 (13), was for many years the only source of information on 'alkali' tolerance of crops and 'alkali' soils for the Prairie Provinces. This work was carried on by the Division of Chemistry of the Dominion Experimental Farms for the Reclamation Service of the Department of the Interior, to provide Canadian data for the classification of lands in certain areas of Southern Alberta as irrigable or non-irrigable. Palmer's (11) work for the Canadian Pacific Railway Company in the same area remained inaccessible for 18 years after the investigations were completed. The most recent work on the effect of 'alkali' salts on plant growth is that of Doughty and Stalwick (1) in connection with an irrigation project developed under the Prairie Farm Rehabilitation Act.

Although salinity problems are most commonly associated with irrigation farming, they are of frequent concern to dry land farmers as well. In Saskatchewan this is true of a number of widely distributed soil series (15), and has been discussed by Mitchell (10) and MacFarlane (9). In the absence of water and drainage to accomplish permanent improvement by the removal of soluble salts, the choice of crops for land of this kind is of particular importance. This was recognized by the United States Department of Agriculture in the early days of the development of western lands and by Gedroiz (2) who suggested more than twenty years ago that plant breeders might develop salt tolerant varieties and strains of crops. Another common suggestion is that of "growing out" the salts by using tolerant crops following them with others of greater economic value. The improvement attributed to the removal of salt by the crop results in a large measure from changes in the vertical distribution of the salts resulting from cultivation.

Whatever approach to the problem is to be used, it is desirable, first, to characterize the soil and to know something of its relations to the crops which it may be expected to produce. This has been done with some success

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by relating observations of natural vegetation and soil characteristics for local conditions (4, 5, 12), but quantitative data are extremely difficult to obtain. A number of investigators have drawn attention to the large variations in the salt distribution in small areas and to the complexity of problems that studies of the soil solution have been expected to solve (6, 7, 8), particularly with reference to the tolerance of crops. The results reported in this paper contribute information on the composition of the salts, range of concentration encountered, and relative tolerance of cereal crops on the saline soils in Saskatchewan. The difficulty, common to all studies, of relating field observations to analytical soil data is emphasized also.

SAMPLING

In commencing the saline soil investigations it was hoped that information on crop tolerance could be combined with a general survey that would provide information on the relations between soil, parent material and the nature of the saline conditions that prevailed locally. Later it appeared advisable to carry on a less extensive program of sampling. Thus during the seasons 1936 to 1939 soil samples from various parts of Saskatchewan were collected from cultivated fields in an effort to arrive at a measure of the salinity tolerance of the three commonly grown cereal crops: wheat, oats and barley. Although it was recognized that factors other than salinity may have contributed to the condition of the crop on these areas, the choice of individual sample sites was determined by the apparent crop tolerance limits, i.e., at the edge of the area of failure or on the boundary of moderately good growth.

Samples collected in 1936 represent a wide range of soil and climatic conditions. Because of excessive drought, sampling in 1937 was restricted to the north central area of Saskatchewan, in the territory mapped predominately as Oxbow, Yorkton and Blaine Lake series (15), where the drought was less severe. The program for the succeeding years was less extensive as it was felt that the information from less widely separated areas might be more readily interpreted.

Sampling in 1936 varied somewhat from that followed in subsequent years when a more uniform practice of taking the samples from the surface 6 inches of soil and the subsoil at 6 to 12 inches was adopted. In some instances deeper samples were taken in 6-inch sections, i.e., 12 to 18 and 18 to 24 inches. Subsoil samples were omitted in many cases or separated on an horizon basis in the first year. However, as the salt concentrations were within the zone of root penetration in every case, samples have been treated as being uniform for the purposes of summarizing the data in Table 1. Each sample, except in 1936, consisted of a composite of soil from two locations where crop conditions were similar.

In 1937 and 1938 data were obtained on barley, wheat and oat varieties grown in adjacent plots on a saline area on the Dominion Illustration Station located at Hafford, Sask.

Soluble salts for each sample were determined gravimetrically on 1 : 5 water extracts. Calcium, magnesium, sodium, sulphate, chloride, carbonate and bicarbonate ions were determined. Some direct determinations of sodium were made in 1937 and 1938 and found to agree closely with the estimations made by difference. Very small amounts of potassium were found in the extracts, therefore it was not determined in the routine analyses; sodium was calculated by difference. The results are expressed as percentage of air dry soil.

RESULTS

I. Range of Salt Concentrations

In Table 1 a frequency distribution of the salt concentrations found in various samples collected from wheat, oat and barley fields in 1936 to 1938 is given over all depths of sampling. Various factors that can be assessed only with a knowledge of seasonal and local conditions undoubtedly contribute to the extreme range of concentrations recorded, therefore it is not feasible to draw definite conclusions from these data concerning the

Table 1.—Range of salt concentrations found in cultivated fields*

Crop		Concentrations of salts, less $CaSO_4$ as percentage of air dry soil												Totals
		0.00–0.20	0.21–0.40	0.41–0.60	0.61–0.80	0.81–1.00	1.01–1.20	1.21–1.40	1.41–1.60	1.61–1.80	1.81–2.00	2.01–2.20	2.21–2.40	
		Frequency												
Barley	1936			4	3	3	1	2	9	1				23
	1937		1	2		1	3	5						12
	1938				2	1						1		4
Oats	1936	10	10	10	13	5	4	5	3	2	1	2	2	67
	1937		1	4	3	1	2	3	2					16
	1938			2	2	2	3		1					10
Wheat	1936	22	17	17	16	14	9	14	5	3	2			119
	1937	1	4	6	4	6	4	7	1					33
	1938			5	4	7	4	1	2	1				24
		Percentage of total												
Barley	3 yrs.		2.6	15.4	12.8	12.8	10.3	18.0	23.1	2.6		2.6		39
Oats	3 yrs.	10.8	11.8	17.2	19.4	8.6	9.7	8.6	6.4	2.2	1.1	2.2	2.2	93
Wheat	3 yrs.	13.1	11.9	15.9	13.6	15.3	9.7	12.5	4.5	2.3	1.1			176
Total		10.7	10.7	16.2	15.3	13.0	9.7	12.0	7.5	2.3	1.0	1.0	0.6	308

* Samples are of surface and subsoil, taken to approximate the "limit of tolerance" of the various crops.

relative tolerance of the three crops. However, from more detailed information with regard to rainfall, surface drainage, soil texture and cropping history, it is possible that specific applications might be made for restricted locations. This will be considered in more detail in Section III.

The number of samples collected for each crop reflects its acreage and importance, and does not necessarily indicate that harmful effects of salinity are encountered more frequently in wheat and oats than in barley. It is commonly believed that barley and oats are more tolerant than wheat, and evidence indicating this will be presented later, but here it may be observed that samples from wheat and oat fields are relatively much more frequent in the two lowest classes than those from barley fields, especially in 1936.

II. Composition of the Salts

It is not feasible to give results in detail for all of the samples examined, but relevant data are given in Tables 2 and 3 to show the composition of the salts in these soils. It is evident that sulphates of calcium, sodium and magnesium predominate. Chlorides are seldom found in appreciable quantities, nor are carbonates. The bicarbonate ion concentration is fairly constant for all samples, suggesting an equilibrium with the carbonates and dissolved carbon dioxide.

Local concentrations of chloride salts and of sodium carbonate have been described by Mitchell (10) and are occasionally encountered but, in general, the salinity problems arise from an excess of sodium and magnesium sulphates. The latter has been considered less toxic than the sodium salt by some investigators (3, 11); however, in view of the mixed constitution of the salts, these data do not permit evaluation of their relative toxicities.

Calcium sulphate is frequently the predominant salt, often reaching the limit of its solubility in the soil : water ratio used for extracting. This salt is not considered to have a harmful effect on plants because of its low solubility; also an ameliorating influence on the effects of sodium and magnesium salts has been reported (11, 17). In order to arrive at a better estimate of salinity of these soil samples, the calcium ion has been calculated to its equivalent percentage of calcium sulphate and subtracted from the total salts. While this is not a strictly reliable calculation the amounts of calcium bicarbonate and other calcium salts are usually quite small and no serious error is introduced.

III. Local Differences Between Crops

The data in the preceding section are of value as a general source of information concerning the salt concentrations encountered in ordinary farming practice in Saskatchewan, but as already intimated they are quite restricted in their application to the question of differences between crops. It is of interest, therefore, to consider data from samples collected from areas in the same or contiguous quarter sections. A number of samples included

TABLE 2.—COMPOSITION OF THE WATER EXTRACTS OF SOILS FROM SELECTED LOCATIONS, SAMPLED IN 1936, 1937 AS PERCENTAGE OF AIR DRY SOIL

	Depth of sample	Salts	$CaSO_4$	Salts less $CaSO_4$	$SO_4^=$	Cl^-	HCO_3^-	Ca^{++}	Mg^{++}	Na^-	pH	Texture
1936												
Barley	0–6	3.90	0.77	3.13	2.741	0.006	0.060	0.226	0.399	0.345	8.3	CL
Oats	0–6	2.17	0.79	1.38	1.490	0.009	0.069	0.232	0.184	0.152	8.0	LL
Oats	0–6	1.15	0.42	0.73	0.800	0.008	0.043	0.123	0.059	0.167	7.6	CL
	6–14	1.34	0.33	1.01	1.192	0.007	0.033	0.100	0.077	0.109	8.7	SiC
Wheat	0–6	0.54	0.23	0.31	0.385	0.000	0.036	0.066	0.074	0.008	7.7	L
	6–12	0.16	0.11	0.05	0.074	0.004	0.053	0.033	0.012	0.013	7.7	CL
Barley	0–6	2.19	0.77	1.42	1.498	0.057	0.044	0.216	0.166	0.211	8.0	LL
Wheat	0–6	1.82	0.78	1.04	1.296	0.001	0.044	0.230	0.163	0.079	7.7	L
Barley	0–6	0.85	0.33	0.52	0.558	0.009	0.047	0.098	0.061	0.076	7.8	L
	6–12	1.29	0.29	1.00	0.900	0.029	0.040	0.088	0.090	0.208	8.1	C
Oats	0–6	1.07	0.62	0.45	0.722	0.006	0.044	0.183	0.061	0.000	8.0	L
	6–12	2.38	0.80	1.58	1.642	0.015	0.024	0.234	0.168	0.224	9.0	CL
Wheat	0–6	1.33	0.47	0.86	0.983	0.001	0.046	0.138	0.128	0.102	7.7	L
Oats	0–6	2.54	0.74	1.80	1.770	0.002	0.044	0.219	0.263	0.130	7.9	L
Barley	0–6	2.30	0.72	1.58	1.618	0.004	0.054	0.211	0.226	0.144	7.8	SiCL
Oats	0–6	1.26	0.51	0.75	0.835	0.074	0.030	0.151	0.118	0.130	7.3	L
Wheat	0–6	1.70	0.75	0.95	1.158	0.014	0.050	0.221	0.068	0.103	7.5	CL
Oats	0–6	3.02	0.78	2.24	2.160	0.020	0.054	0.228	0.315	0.228	8.0	CL
	6–12	0.99	0.44	0.45	0.734	0.009	0.043	0.129	0.104	0.039	8.0	SiC
Wheat	0–6	2.46	0.78	1.68	1.722	0.001	0.061	0.230	0.238	0.130	7.6	L
	6–12	1.71	0.58	1.13	1.202	0.001	0.046	0.170	0.150	0.130	7.8	CL
1937												
Barley	0–6	1.69	0.43	1.26	1.205	0.004	0.041	0.130	0.181	0.082	7.8	C
	6–12	2.07	0.69	1.38	1.480	0.000	0.031	0.204	0.217	0.084	8.5	C
Oats	0–6	0.93	0.16	0.77	0.585	0.001	0.049	0.047	0.171	0.006	8.6	L
	6–12	0.34	0.04	0.30	0.105	0.003	0.068	0.012	0.000	0.153	9.2	C
Wheat	0–6	0.99	0.20	0.79	0.645	0.004	0.046	0.059	0.105	0.102	8.6	LL
	6–12	1.05	0.26	0.79	0.719	0.000	0.038	0.076	0.110	0.081	9.0	C L
Barley	0–6	2.10	0.73	1.37	1.430	0.002	0.044	0.215	0.224	0.067	8.3	LL
	6–12	0.91	0.43	0.48	0.584	0.000	0.041	0.130	0.052	0.058	8.4	SiC
Oats	0–6	2.32	0.84	1.48	1.635	0.016	0.041	0.249	0.236	0.081	7.8	SiL
	6–12	2.40	0.83	1.57	1.755	0.014	0.025	0.245	0.254	0.094	8.6	L
Oats	0–6	1.36	0.50	0.86	0.938	0.000	0.036	0.147	0.134	0.055	8.4	SL
	6–12	1.44	0.92	0.52	1.005	0.000	0.027	0.270	0.088	0.035	8.5	CL
Wheat	0–6	2.14	0.82	1.32	1.492	0.000	0.036	0.239	0.227	0.067	8.0	C
	6–12	1.57	0.91	0.66	1.135	0.000	0.053	0.268	0.137	0.001	8.3	CL

C = clay; L = loam; LL = light loam· Si = silt; SiCL = silt clay loam.

TABLE 3.—COMPOSITION OF WATER EXTRACTS OF PRELIMINARY SAMPLES FROM CEREAL VARIETY EXPERIMENTAL AREA; RESULTS AS PERCENTAGE OF AIR DRY SOIL

Sample	Depth of sample in.	Total salts	$CaSO_4$	Salts less $CaSO_4$	$SO_4^=$	HCO_3^-	Ca^{++}	Mg^{++}	Na^+
1937									
1. Sweet clover stubble	0–8	0.38	0.12	0.26	0.251	0.054	0.036	0.036	0.085
	8–16	0.49	0.17	0.32	0.204	0.057	0.051	0.032	0.074
	16–20	0.10	0.04	0.06	0.050	0.055	0.014	0.014	0.021
	20–36	0.09	0.09	0.00	0.049	0.046	0.029	0.014	0.011
	26–30	0.11	0.06	0.05	0.054	0.046	0.018	0.004	0.035
2. Sweet clover stubble	0–8	0.48	0.10	0.38	0.217	0.112	0.031	0.060	0.060
	8–16	2.16	0.77	1.39	1.598	0.032	0.228	0.197	0.164
	16–24	1.56	0.17	1.39	1.194	0.036	0.051	0.175	0.182
	24–30	1.21	0.08	1.13	1.009	0.026	0.024	0.146	0.197
3. New breaking	0–8	1.60	0.71	0.89	1.194	0.032	0.213	0.151	0.063
	8–16	2.63	0.73	1.90	1.892	0.029	0.217	0.244	0.209
	16–24	1.68	0.07	1.61	1.248	0.029	0.020	0.211	0.215
	24–30	1.52	0.08	1.44	1.110	0.032	0.024	0.211	0.125
4. New breaking	0–6	0.43	0.12	0.31	0.241	0.039	0.037	0.040	0.061
	6–12	1.70	0.49	1.21	1.234	0.032	0.147	0.175	0.111
	16–24	2.08	0.30	1.78	1.508	0.026	0.180	0.199	0.156
1938									
1. Barley emerged	0–6	0.24	0.09	0.15	0.161	0.087	0.026	0.026	0.032
	6–12	2.04	0.85	1.19	1.545	0.027	0.250	0.176	0.132
	12–18	2.04	0.86	1.18	1.545	0.029	0.254	0.171	0.138
	18–24	1.78	0.83	0.95	1.431	0.020	0.245	0.168	0.105
2. Barley failed to emerge	0–6	2.63	0.78	1.85	1.985	0.086	0.230	0.307	0.150
	6–12	1.85	0.48	1.47	1.462	0.050	0.140	0.190	0.200
	12–18	1.37	0.45	0.92	1.068	0.038	0.132	0.145	0.103
	18–24	1.29	0.46	0.83	1.060	0.036	0.136	0.127	0.125

in Table 1 have been chosen for this purpose and the details of the composition of the water extracts, pH and texture classification summarized in Table 2.

In addition to these samples, others from the crop variety experiments in 1937 and 1938 are considered in Tables 4 and 5. The area used for the variety experiments was located on low land traversed by a small creek, subject to spring flooding and having a high water table. The soil is a heavy alluvial deposit, highly calcareous, with moisture conditions such that even in dry years it is capable of producing large crops of fodder. The experimental plots in 1937 were on newly broken land adjacent to a small field that had produced a large crop of sweet clover in 1936. Those in 1938 were also on newly broken land, the strips being seeded across the end of a small slough with a salt gradient from the bottom to the slopes on either side. Single drill strips of the varieties of wheat, oats and barley listed in Tables 4 and 5 were used.

TABLE 4.—SUMMARY OF VARIETY TESTS FOR SALT TOLERANCE 1937. WATER SOLUBLE SALTS AS PERCENTAGE OF AIR DRY SOIL

Crop and variety	Depth of sample in.	Growth failed		Growth distressed		Growth moderate to good	
		Total salts	Salts less $CaSO_4$	Total salts	Salts less $CaSO_4$	Total salts	Salts less $CaSO_4$
Wheat							
Marquis	0–8			0.43	0.39	1.05	0.70
	8–14			0.48	0.34	1.44	1.08
Thatcher	0–8			0.53	0.48	0.71	0.43
	8–14			0.26	0.21	1.61	0.93
Pelissier*	0–8	0.79	0.67	0.89	0.64	0.79	0.56
	8–14	0.43	0.36	2.01	1.24	1.75	0.90
Average for wheat	0–8	0.79	0.67	0.62	0.50	0.85	0.58
	8–14	0.43	0.36	0.92	0.60	1.60	0.97
Oats							
Gopher	0–8			0.66	0.48	1.37	0.77
	8–14			2.10	1.44	1.64	0.99
Banner (1)	0–8			1.72	1.03	0.51	0.40
	8–14			2.26	1.47	1.32	0.88
Banner (2)	0–8	1.41	1.05			0.34	0.23
	8–14	0.85	0.74			1.32	1.06
Average for oats	0–8	1.41	1.05	1.19	0.76	0.74	0.47
	8–14	0.85	0.74	2.18	1.46	1.43	0.98
Barley							
Regal	0–8			2.42	1.84	0.86	0.65
	8–14			2.36	1.58	1.89	1.39
Trebi	0–8			1.37	0.95	0.65	0.46
	8–14			1.13	0.81	1.40	0.74
Average for barley	0–8			1.90	1.40	0.76	0.56
	8–14			1.75	1.20	1.65	1.06

* Pelissier—durum wheat.

The results of the examination of preliminary samples taken from this area are given in Table 3. Four samples were obtained in April, 1937, two from the sweet clover stubble and two from the area of new breaking. These were taken on the basis of horizon differences to the depths that the ground was unfrozen. Sample 2 was taken from a part of the sweet clover area where growth had been distressed; the values shown probably closely approach the limit of tolerance for sweet clover on this soil. They may be compared with sample 1 from an area of good growth. The 1938 samples were obtained in June just after the crops had emerged. These were

taken at four equal depth intervals to 24 inches. The comparison is between the part of the area where there was no emergence and where Regal barley had made a start. At this time the plots gave little promise of surviving as the spring had been quite dry.

Samples from the cereal variety plots were taken on July 12, 1937. Growth had been difficult because of the prolonged drought but the crops had headed and were moderately good in places, particularly the barley.

TABLE 5.—SUMMARY OF VARIETY TESTS FOR SALT TOLERANCE 1938. WATER SOLUBLE SALTS AS PERCENTAGES OF AIR DRY SOIL

Crop and variety	Depth of sample in.	Growth failed		Growth distressed		Growth moderate to good	
		Total salts	Salts less $CaSO_4$	Total salts	Salts less $CaSO_4$	Total salts	Salts less $CaSO_4$
Wheat							
Marquis	0–6	2.68	2.31	1.81	1.12	1.01	0.68
	6–12	1.99	1.28	1.39	1.04	0.66	0.45
	12–18	1.45	0.90	1.46	1.17	0.46	0.28
Pelissier	0–6	1.94	1.40	1.46	1.08	1.04	0.66
	6–12	1.41	1.15	0.97	0.79	0.53	0.39
	12–18	1.01	0.74	0.90	0.72	0.36	0.23
Average	0–6	2.32	1.86	1.68	1.10	1.02	0.67
	6–12	1.70	1.22	1.18	0.92	0.60	0.42
	12–18	1.23	0.82	1.18	0.94	0.41	0.26
		Thin stand, delayed maturation		Moderate stand		Good stand, normal maturation	
Oats							
Gopher	0–6	2.31	1.68	1.62	1.19	0.97	0.64
	6–12	1.30	0.99	1.10	0.81	0.66	0.43
	12–18	1.28	0.88	1.24	0.99	0.47	0.34
Banner	0–6	2.27	1.64	0.70	0.48	0.69	0.44
	6–12	1.41	1.12	0.78	0.60	0.50	0.30
	12–18	1.22	0.90	0.76	0.59	0.50	0.32
Average	0–6	2.29	1.66	1.16	0.84	0.83	0.36
	6–12	1.36	1.06	0.94	0.70	0.58	0.36
	12–18	1.25	0.89	1.00	0.79	0.48	0.33
				Moderate stand delayed maturation		Good stand normal maturation	
Barley							
Regal	0–6			2.31	1.62	1.40	0.95
	6–12			1.05	0.76	0.82	0.49
	12–18			0.72	0.44	0.47	0.22

Pairs of samples were taken from areas where the crops were growing and where they had failed or were visibly distressed. In each case surface and subsoil samples were obtained (0 to 8 in., 8 to 14 in.).

On August 20, 1938, samples were obtained from the plots for that year. All the crops were advanced to maturity except where affected by the salinity of the soil. Again samples were obtained from areas of failure, distressed growth, and moderate to good growth. This year sampling was done at three depths, namely 0 to 6 in., 6 to 12 in., 12 to 18 in. In both years, samples were withdrawn from composites of soil dug at two locations. Summaries of the total salts and residual salts after subtracting calcium sulphate are given in Table 4 for 1937 and Table 5 for 1938.

Inspection of Table 2 demonstrates the difficulty of obtaining consistent results with respect to the relative tolerance of wheat, oats and barley, even from closely related groups of samples. The results of the variety experiments are only slightly more encouraging. The greater tolerance of barley is evident but the results for wheat and oats are less clear cut. In 1937 the wheat results were anomalous, better growth being obtained at the higher salt concentrations. No variety[3] differences could be demonstrated from these data, therefore the results have been averaged for crops.

These data do demonstrate, however, that common cereal crops can be grown on land fairly high in soluble salt content. Oats and even wheat have survived 1.00% of sodium and magnesium sulphate while barley was growing with 1.62% of salts in the surface soil. The most noticeable effect on the barley and oats was the delay in ripening, and somewhat thinner stand.

DISCUSSION

It is evident from the foregoing results that the appearance of vegetation cannot be related consistently to analytical data from single or composite samples taken to represent certain conditions of growth. Factors other than salinity or alkalinity may be responsible for the failure of a crop, adding to the common difficulties that are associated with sampling a heterogeneous body such as soil. Furthermore, abrupt variation in salt concentration within small areas is common (7) so that a plant may have access to a variety of conditions which cannot be readily integrated by sampling and analysis.

The important question of the depth at which salts may exist without proving harmful was obscured by grouping the data as was done in Table 1, but consideration of this point involves a knowledge of the seasonal moisture conditions of the soil and the effects of precipitation and evaporation on salt movement. In so far as cultivation and cropping may affect this movement, salts in the subsoil constitute a potentially harmful factor, even on dry land farms.

The presence of high gypsum concentrations in many of the calcareous saline soils is responsible in part for the infrequent occurrence of sodium carbonate or "black alkali". Apart from any ameliorating or antagonistic influence that may be ascribed to this salt or to the effect of calcium ion,

[3] In 1938, Thatcher wheat and Trebi barley were omitted through a misunderstanding with the farm operator.

the high calcium in the water extract will have a bearing on the composition of the exchangeable bases and thereby favourably influence the physical properties of the soil.

The results indicate that, of the commonly grown crops in Western Canada, barley is most likely to succeed on saline soils. This is in agreement with the statements of Harris (3), Kearney and Scofield (6), Shutt (14), Palmer (11), and common observations of farmers. Barley, oats or wheat are more likely to succeed as hay than as grain crops, although barley will produce seed under very adverse conditions. This should be borne in mind, for saline areas often have a favourable moisture reserve, and therefore may produce feed in dry seasons. A crop cover is important in preventing salt accumulation at the surface of the soil, therefore cereals or sweet clover may prove useful as preliminary or cover crops in establishing a stand of alfalfa.

The salt concentrations recorded are somewhat higher than those listed by Kearney and Scofield (6) in their classification of crops according to the degree of tolerance toward salinity. They place barley for hay in their medium-strong salinity group, 0.6 to 0.8%, and for grain along with oats and wheat for hay at 0.4 to 0.6% in the medium group. Sweet clover also is listed in the medium-strong group. Wyatt (16) suggested 0.75% as the upper limit of salts (other than calcium sulphate) in crop land. These figures all refer to salts in which sulphate is the dominant anion. Shutt (13) gives 0.35% of sodium sulphate as the limit of tolerance for wheat, and he considered an 'alkali' content approaching 1.0% as beyond the "limit of tolerance for good, vigorous growth". Doughty and Stalwick (1) found in greenhouse experiments with a heavy clay soil in which sodium sulphate predominated that 0.4% of salts permitted a fair growth of alfalfa, wheat and oats. Yields fell off considerably above that concentration.

The range between 0.4 and 1.0% is considerable and leaves much room for doubt concerning the possible utilization of dry land salines. However, the fact that some crops can be grown under apparently excessive conditions of salinity is an encouraging feature.

The utilization and management of saline soils cannot be undertaken without modifying existing farm practice somewhat and incurring added expense. In a land conservation and rehabilitation program such soils should not be overlooked, as they tend to degenerate into very poor pasture through overgrazing or, when cultivated, may become a breeding ground for halophytic weeds.

Apart from the economic aspects associated with these soils there is a large and interesting field of investigation for the ecologist and the pedologist. No attempt as yet has been made with these data to establish zones in which various salts predominate, but it is expected that this will be done and the results related in part to the material from which the soils are derived. There is also a considerable field for investigation of the natural halophytic vegetation with reference to its nutritional value.

SUMMARY

Soil samples from various parts of Saskatchewan were collected during 1936 to 1939 in an effort to arrive at a measure of the salt tolerance of the

three commonly grown cereal crops: wheat, oats and barley. In 1937 and 1938 varieties of these crops were grown in adjacent plots on saline soil from which samples were taken representing three conditions of growth.

Sulphates of sodium, magnesium and calcium are the main salts found in these soils. A wide range of concentrations was encountered in samples taken from sites that were chosen to represent the limits of salt tolerance of the crops. A good stand of barley of somewhat delayed maturity was found in soil containing 1.6% of mixed sodium and magnesium sulphates, and wheat survived at 1.0%. These are excessively high values but serve to indicate the possibilities of utilizing special areas of favourable moisture conditions.

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REFERENCES

1. Doughty, J. L. and A. E. Stalwick. The effect of alkali salts on plant growth. Sci. Agr. 20 : 272-276. 1940.
2. Gedroiz, K. K. Journal of Experimental Agronomy, VI, 1917, from collected papers translated by S. A. Waksman, edited by C. S. Scofield. U.S. Dept. of Agriculture. 1923.
3. Harris, F. S. Soil Alkali, John Wiley & Sons, New York. 1920.
4. Hilgard, E. W. Soils. The MacMillan Co., New York. 1906.
5. Joffe, J. S. Pedology. Rutgers University Press, New Brunswick, N.J. 1936.
6. Kearney, T. H. and C. S. Scofield. The choice of crops for saline land. U.S. Dept. of Agric. Circ. No. 404. 1936.
7. Kelley, W. P. The variability of alkali soil. Soil Sci. 14 : 177-189. 1922.
8. Kelley, W. P. The effect of dilution on the water soluble and exchangeable bases of alkali soils and its bearing on the salt tolerance of plants. Soil Sci. 47 : 367-375. 1939.
9. MacFarlane, David L. Agricultural land utilization in Saskatchewan. Master's Thesis, University of Saskatchewan, 1934 (unpublished).
10. Mitchell, J. "Alkali" soils in Saskatchewan. Sci. Agr. 18 : 120-125. 1937.
11. Palmer, A. E. Kind, position and toxicity of alkali salts in certain Alberta irrigated soils. Sci. Agr. 18 : 132-140. 1937.
12. Shantz, H. L. and R. L. Piemeisel. Types of vegetation in Escalante Valley, Utah, as indicators of soil conditions. U.S. Dept. of Agric. Tech. Bull. 713. 1940.
13. Shutt, Frank T., *et al.* Trans. of the Royal Society of Can. Sec. III. 1918, 1921, 1922, 1923.
14. Shutt, Frank T. Alkali soils, their nature and reclamation, Dept. of Agric. Canada Bull. No. 21. 1927.
15. University of Saskatchewan, Soil Survey Report No. 10. 1936.
16. Wyatt, F. A. Report W. Canadian Soc. of Agronomy Meeting, Lethbridge. 1939.
17. Wyatt, F. A. and J. L. Doughty. The sulphur content of Alberta soils. Sci. Agric. 8 : 549-555. 1928.

ROOT DEVELOPMENT IN OAT VARIETIES[1]

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Varieties of oats often differ widely in many characteristics, and it is through such variability that certain combinations of characters have been brought together to form the basis of improvement. In the case of oats, as with other crops, the above-ground portion of the plant has offered the greatest possibilities for study and selection, whereas the root characters have received comparatively little attention, particularly from the standpoint of breeding better varieties. The study of fine differences in root development not only requires special technique in obtaining suitable material but such work is very laborious.

In studying varietal characteristics in relation to lodging in oats, the authors have, during the past three years, made certain observations on differences between varieties in root development, and have collected a limited amount of data which on the whole substantiate these observations. The junior author has made an extensive study of the factors related to lodging in oats and has pointed out the importance of root development as a factor in lodging resistance.

REVIEW OF LITERATURE

Caffrey and Carroll (1), to the knowledge of the authors, have been the only investigators to study differences in the root development of oat varieties. They found that varieties differing in strength of straw also differed in root development. Various types of root growth were demonstrated in the varieties under test. The strong strawed varieties had a better anchored rooting system than those varieties most susceptible to lodging. Hybridization among these varieties has shown that root type is a character controlled by genetical factors and that segregation for root type was evident. From histological studies it was observed that no significant differences in root structure existed between the varieties studied.

Howard and Howard (2) considered a well developed root system to be important in the prevention of lodging in wheat. In genetical studies it was found that there was distinct segregation for root type.

Hamilton (3) concluded that type of root growth was associated with certain above ground plant characters that appear to be related to strength of straw in oats.

A good deal of work has been published on the relationship between root morphology and lodging in corn. Selfed lines of corn have been shown to differ in depth, width and volume of root clump, and length and angle of brace roots. These differences between lines have been associated with differences in lodging.

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RESULTS AT OTTAWA

The work on root development in oats at Ottawa, while not extensive, covers a period of three years and, as noted above, has been incidental to a more elaborate project dealing with plant characters related to straw strength. In 1938, preliminary field observation indicated a definite relationship between straw strength and root development and stimulated further work with roots. In the spring of 1939, five varieties were chosen as representing three different types of root development. Seed of these was grown in pure quartz sand fed with nutrient solution in the greenhouse. Three plants of each of the five varieties were grown in separate porcelain lined pots and replicated four times. These plants were grown until after reaching the full heading stage and then carefully removed from the sand. Figure 1 shows a representative plant of each variety at the

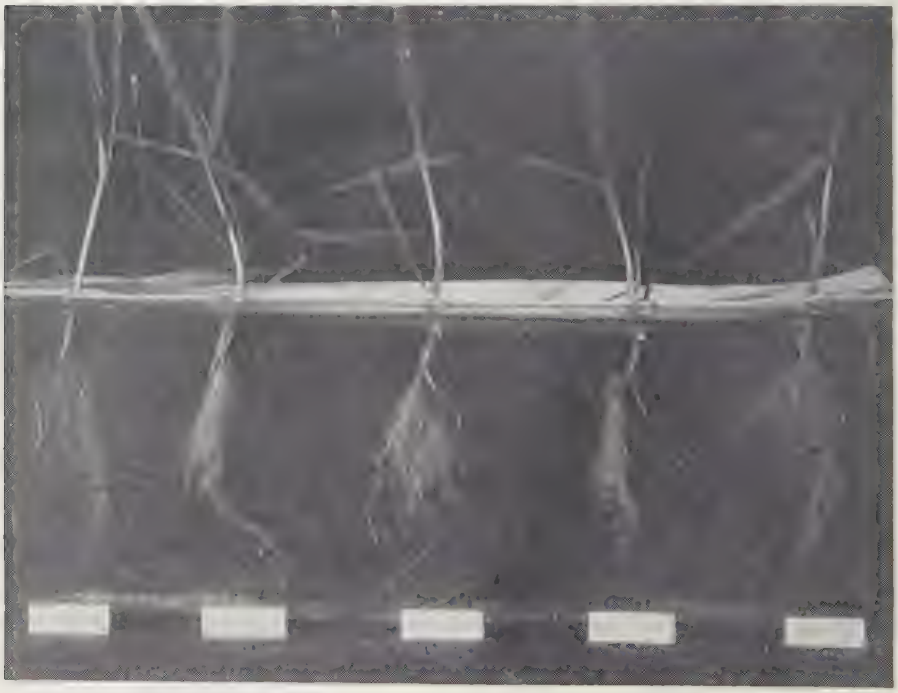

FIGURE 1. Root development of 5 oat varieties, grown in pure sand with nutrients supplied in solution. Left to right: Waterloo, Old Island Black, Victory, Don de Dieu and Acton.

third leaf stage. The varieties Acton, Waterloo and Victory show a tendency towards more branching root systems, the two former varieties being somewhat coarser. The varieties Old Island Black and Don de Dieu are known to be among the weaker strawed varieties and carry a much finer type of root system with little tendency to spread. Observations on the same material at full heading showed similar differences between these varieties.

During the summer of 1940, a similar group of varieties was grown under field conditions, that is, in drills 7 inches apart. The soil used was

classified as sandy loam. At maturity 60 plant roots from each variety were loosened with a shovel to a depth of approximately 10 inches, when the soil was moist following a light rain. These roots were carefully removed,

FIGURE 2. Comparative variation in root development of 5 oat varieties as grown under field conditions. Varieties in order from top: Acton, Ardri, Victory, White Cross and Old Island Black.

taking precaution not to damage the upper part of the root system. After washing, 8 roots were taken at random for photographing as shown in Figure 2. This illustrates the amount of variation in type of root growth within varieties. The spreading habit of root growth in the case of the

strong strawed variety Acton and to a more moderate degree Ardri and Victory, in contrast to the weak strawed varieties White Cross and Old Island Black, can also be noted. Since the fibrous roots in all cases have largely been removed, either in the process of digging or washing, the remaining branch roots, as shown in the photograph, represent the relative anchorage capacity of the varieties shown.

In order to obtain some data on the actual amount of growth in the varieties under test, the total dry weight was taken on the roots and tops of 60 plants as well as the average number of branch roots per plant. These data are shown in Table 1.

TABLE 1.—DATA OBTAINED FROM ROOTS AND TOPS OF FIVE OAT VARIETIES, 1940

Variety	Dry weight from 60 plants		Average number branch roots per plant	Ratio of root to top
	Roots	Tops		
	gms.	gms.		
Acton	14.8	152	16.8	1 : 10.3
Ardri	12.6	93	11.5	1 : 7.4
Victory	11.7	113	13.4	1 : 9.7
White Cross	8.4	103	10.0	1 : 12.3
Old Island Black	6.9	85	10.7	1 : 12.3

This work confirms previous observations on the relation between quantity and coarseness of branch or anchorage roots and lodging resistance. In the above table is shown the dry weight of the roots and tops of 60 plants from each variety and the average number of branch roots per plant. The latter represents the roots which branch out from the crown i.e., the whorls of adventitious roots which grow from the lower nodal regions of the main stem. These results show that strong strawed varieties such as Acton and Ardri, have a greater bulk of roots as pointed out by the high dry weights. The weak strawed varieties such as White Cross and Old Island Black have less extensive root systems, hence a dry weight which is low. The ratio of the weight of top growth to root growth varies from 7 : 1 to 12 : 1 depending on the variety. The weight of top growth alone appears to have no consistent relationship to lodging. In accordance with the greater bulk of roots the strong strawed varieties also have the highest average number of branch roots per plant.

Through the co-operation of Dr. Woodward of the Division of Chemistry, Central Experimental Farm, the roots in this test have been analysed for cellulose. While the chemical data in a general way indicate that the varieties with heavy branch root growth are low in cellulose in comparison with varieties carrying a small amount of branch root growth, no definite conclusions can be made at present since the data are based only on one test.

In 1941 this work was continued in the field with four varieties. Twelve plants of each variety were grown under spaced conditions 3 feet apart each way on similar soil to that used the previous year. The seeds used for this test were selected from a bulk lot germinated on blotting paper.

This made it possible to obtain uniform seedlings. At maturity the 12 plants were removed from the soil by digging around each plant so as not to injure the roots. Owing to the extremely dry summer, and to the shallowness of the surface soil, the mass of soil necessary to lift with each

FIGURE 3. Representative roots of 4 oat varieties as grown under spaced conditions in the field. Left to right: Acton, Old Island Black, Vanguard and White Cross.

plant was comparatively small. After washing the roots, 4 were chosen for photographing one representing each variety. The root systems of these four plants which are all shown in Figure 3, are representative of the 12 grown of each variety.

The difference in total amount of root growth in these four varieties is very striking. It is also evident that the number and coarseness of coronal roots bear little relation to total mass of root growth. As shown above, the variety Acton is characteristic in producing a heavy, coarse growth of branching anchorage roots. In contrast to this variety, White Cross shows weakness both in total mass of root and also in anchorage roots which are so necessary in resisting conditions which favour lodging. While the root growth of the varieties Old Island Black and Vanguard appear quite similar in the illustration, there is actually considerable difference in quantity and coarseness of coronal roots in favour of Vanguard.

CONCLUSION

From the limited amount of work reported in this paper, it seems significant that oat varieties differ widely in total mass of root growth as well as in number and coarseness of anchorage roots. There is a definite relation between type of root growth and resistance to lodging.

Good root development with substantial anchorage is an important varietal character in resisting conditions favourable to lodging. Also, the ability of a variety to absorb plant nutrients and tolerate soil borne diseases is undoubtedly closely associated with type of root system.

REFERENCES

1. Caffrey, M. and P. T. Carroll. Lodging in oats. Erie Dept. of Agr. Journ. 35 : 25. 1938.

2. Howard, A. and G. L. C. Howard. On the inheritance of some characters in wheat 1. Mem. Dept. Agr. Ind. Bot. 5 : 1-46. 1912.

3. Hamilton, D. G. Certain oat culm characters and their relationship to lodging. Sci. Agr. 21 : 646. 1941.

SLEEPINESS IN CARNATIONS[1]

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The term "sleepiness" as applied to flowers is usually confined to carnations. It is characterized by a partial closing of the flower due to an incurving or curling of the petals. This condition progresses until the flower is frequently almost closed. The outer petals are markedly curled and usually show a drying and darkening along the margins. The disorder is encountered irregularly, usually when flowers are shipped by train a considerable distance. The flowers do not recover after they have become sleepy, which makes them useless to the retailer, an expense to either the grower or carrier, and a general cause of dissatisfaction.

There was very little known about the cause of this trouble for many years. Various factors were thought to be responsible such as faulty nutrition while the plants were growing in soil, too high growing temperature, insufficient greenhouse ventilation, cutting the flowers too tight, shipping too soon after cutting, holding too long between cutting and shipping, not cooling sufficiently before shipping, cooling too much before shipping, insufficient ventilation during shipping, too much heat during shipping, too cold during shipping, and various other factors.

In 1908 Crocker and Knight (1) investigated the effect of illuminating gas on carnations and found that 12.5 parts per million for 12 hours would cause sleepiness. Using ethylene gas they found that 0.5 parts per million had the same effect. Their tests were made with individual flowers in a tightly-sealed 20 litre glass bottle in the greenhouse at a temperature varying between 68 and 82° F.

Within recent years it was found that carnations stored in the presence of ripe apples became sleepy. Fruits such as apples, pears, peaches, plums, citrus fruits, etc., give off gases, among which is ethylene which is also present in illuminating gas and coal gas. Preliminary investigations with ethylene showed this gas would cause sleepiness at a concentration of 10 parts per million for 24 hours. Illuminating gas at 1000 parts per million (equivalent to less than 40 parts per million of ethylene since Ottawa city gas contains 4.34% of illuminants) for 24 hours had the same effect. There was no indication that these were the lowest effective concentrations. These results supported the findings of Crocker and Knight.

Extensive tests made at one of the largest carnation growers did not reveal any harmful gases. Very sensitive indicator plants were used without any indication of ethylene or any similar gas being present. Carnations stored in various parts of the establishment showed no evidence of sleepiness. From these investigations it appeared that the trouble was not one of growing or culture but more likely caused by some factor during shipment.

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In November and December, 1939, carnation shipments were studied under actual shipping conditions from Toronto to Sudbury, Fort William and Winnipeg. The flowers were packed in ventilated and unventilated cartons. The cartons travelled by express in electrically lighted cars and were stacked with commercial shipments under good conditions with respect to refrigeration and handling. All the flowers arrived at their destinations in excellent condition and after several days were shipped back to their starting point returning on different trains. After the return trip they still showed no signs of sleepiness except those which had been to Fort William. It is possible that fumes from the engine or gas from the small coal stove in the express car may have contained sufficient ethylene to cause sleepiness in that lot. In any event the results clearly indicated that sleepiness was not due to any factor in the cultivation of these flowers but probably due to some factor present during shipment.

In December, 1940, further shipments were studied while in transit from Toronto to Fort William. These flowers travelled under similar conditions to those in the previous investigation except that the express cars were gas lighted and had a gas cooking fixture instead of a small coal stove. The trial lots of flowers used in this investigation were made up as follows:—

Lots 1, 2, and 5: each consisted of three cartons, two of which were cardboard, one with holes in the sides for ventilation and one without ventilation. The third was a cellophane carton to permit observation of flowers without opening the carton.

Lots 3 and 4: each consisted of two cartons, one cardboard carton not ventilated and one cellophane carton.

The flowers for the above cartons were cut on the morning of December 11, 1940, and stored in water in the cold storage until the afternoon when they were packed in the cartons. Each carton contained 30 carnations, made up of 10 Virginia, 10 My Love and 10 Maytime. Lot 5 was sent to Fort William as a regular express shipment in an electrically lighted express car, to be used as a check on the other lots.

At Toronto lots 1, 2, 3, and 4 were taken onto the train for Fort William. There was only one express car to work in and it was very crowded, on account of the approaching Christmas season. It was steam heated and equipped with gas illumination and gas cooking-ring.

The commercial shipments of flowers were stacked on a wood floor-rack and covered with a tarpaulin. Blocks of ice around the cartons took care of refrigeration. More wood racks separating layers of boxes ensured a well distributed ventilation between the boxes. The stack was placed near the front side door. This system of handling appeared to be satisfactory.

The various lots of flowers were treated as follows: Lot 1 was placed under the tarpaulin with the commercial flower shipments. Lot 2 was placed near the rear of the car and on top of other express parcels. This was to give a comparison between the effect of conditions surrounding Lot 1 and the effect of the general atmosphere of the car on Lot 2. The two cartons composing Lot 3 were opened and the open boxes containing the flowers were inverted over the gas cooking-ring. Gas was allowed to

flow from the gas ring up into the flowers for a few seconds after which the boxes were closed and placed in the rear half of the express car. Lot 4 was placed beside Lot 3 to serve as a check without having been gassed. On arrival at Fort William at 10:45 p.m. December 12 the various cartons of flowers were placed in the express room until morning when they were taken to a local florist's shop for storage and observation.

Lots 1, 2, 3, and 4 were removed from the cartons on December 13 a.m. and none of them had the fresh appearance which was present when they were packed. Lots 1 and 2 were somewhat wilted and flaccid-looking, regardless of the container they were in, and had every appearance of sleepiness developing. In Lots 3 and 4 practically all the flowers were definitely "sleepy". The decisive sleepiness apparent in Lot 3 was attributed to the effect of the pintsch gas with which the flowers were treated on leaving Toronto. The sleepiness found in Lot 4 was considered due to the escape of pintsch gas from Lot 3 and entering the cartons of Lot 4 since they were lying side by side in the express car. Probably some effect might also be due to the presence of pintsch gas in the atmosphere of the car, since it could be detected by smell. The presence of such a gas in the car could also be responsible for the doubtful appearance of the flowers in Lots 1 and 2. All the flowers were trimmed and placed in water for future examinations. After 3 to 4 days in water very few of the flowers in Lots 1 and 2 showed any recovery. Most of them passed into even more advanced stages of sleepiness. Lots 3 and 4 showed practically no recovery when placed in water. At the end of 4 days in water only 5 of the 120 flowers in these two lots were not sleepy.

Lot 5, which had been sent as a check shipment in an electrically lighted car, was opened and examined on December 13. These flowers arrived in very good condition and were much fresher in appearance than Lots 1, 2, 3, and 4. There were a few which were slightly wilted and which appeared a little doubtful. However, when trimmed and put in water they regained their freshness and were quite normal. On the fourth day after arrival a few showed some signs of sleepiness. Unfortunately, there was no opportunity to store these flowers separate from Lots 1, 2, 3, and 4 and there is the possibility that their close proximity to these flowers with the likely emanation of gas might have been responsible.

On leaving Fort William on December 17, those flowers which were still in good condition were repacked and brought back on the return trip under several test conditions. However, on arrival all were equally poor and most of them were sleepy and it was felt that the severe treatment these flowers had previously gone through might have been at least partly responsible for their condition.

A number of gas samples were collected during the investigation and were analysed for potassium permanganate-reducing substances by the Division of Chemistry.

Ethylene (a gas which causes sleepiness) will reduce potassium permanganate solution and this is one method of analysing for ethylene when it is in pure mixtures. However, where the gas mixtures are unknown, such as in the express cars, there may be other gases present which will reduce

potassium permanganate but may not have any effect on carnations. Table 1 describes the gas samples collected; the results of the analyses are calculated as parts per million of ethylene in the sample of air, although the gas analysed may not be entirely ethylene.

TABLE 1.—ANALYSES OF GAS SAMPLES COLLECTED DURING INVESTIGATION OF "SLEEPINESS IN CARNATIONS"

Date	Time	Description of sample	Permanganate-reducing substances (as ethylene p.p.m.)
Dec. 11	8.45 p.m.	Air in express car, Brampton to Toronto	37
Dec. 11	12.00 p.m.	Air in express car, near flower shipments, Toronto to Fort William	48
		Air in rear half of express car	40
Dec. 15	11.00 p.m.	Air in express car of train from Toronto on arrival at Fort William	25
Dec. 16	9.00 p.m.	Air in cool room, at florist in Fort William	68
Dec. 16	9.00 p.m.	Air in cellar, at florist in Fort William	34
Dec. 16	11.30 p.m.	Air in express car of train from Toronto on arrival at Fort William	30
Dec. 17	4.00 a.m.	Air in express shed at Fort William	29
Dec. 17	12.00 a.m.	Air in express car Fort William to Toronto	31
Dec. 17	3.15 p.m.	Air in express car, Fort William to Toronto	59

Although the results do not appear to be high, yet the possibility that ethylene is the gas detected would make it detrimental to carnations.

It was mentioned earlier that the trouble was likely caused by some factor present at certain times in the shipping of carnations. It was suggested that this factor may be a gas which in sufficient concentration is harmful to the carnations. The results obtained in the present investigation substantiate this. Although there were no small coal stoves present in the express cars, yet there is always the possibility that coal gases from the engine may drift into the car and collect there in sufficient concentration to be harmful. Probably more likely is the presence and effect of pintsch gas used in the lights and cooking fixtures. This latter possibility seemed so likely that it was made the basis for further investigations at Ottawa.

The Manual of Industrial Chemistry, 3rd Edition, p. 529 states that pintsch gas is made up of,—

Methane	50–60%
Illuminants	30–40%
Carbon monoxide	0.5%
Hydrogen	3.5%
Specific gravity	0.78–0.85

The presence of ethylene is included as part of the illuminants. Analysis of pintsch gas by the Division of Chemistry showed 16% of permanganate-reducing substances expressed as ethylene. This is equivalent to 16,000 parts per million. Through the courtesy of the authorities at the Ottawa Union Station a gas cylinder was filled with pintsch gas to be used for this investigation.

A 44-gallon steel drum was used in which to subject the flowers to various concentrations of the gas. The carnations used were grown in the greenhouses at the Central Experimental Farm. In submitting the flowers to treatment the amount of gas to be used was measured out, introduced into the drum, mixed with the air inside the drum and then the flowers were placed inside the drum through an opening in the top which was immediately closed tight to prevent loss of gas. In every case the flowers were arranged and packed in a carton the same as they would be under actual shipping conditions.

Preliminary tests with unmeasured amounts of gas introduced into the drum showed that pintsch gas would cause sleepiness in carnations. Flowers were gassed from 20 to 48 hours, and within a day after removing from the drum and placing in water a few in every dozen so treated would be sleepy and the remainder very doubtful looking. A day or so later practically all, if not every one, would be tightly curled and dead because

FIGURE 1. Check group of flowers, not treated.

of sleepiness. A number of tests were carried out with the drum located in one of the cool greenhouses. Varying quantities of pintsch gas were measured into the drum. The highest measured quantity used was sufficient to give 625 parts per million of pintsch gas in the drum. On the basis of containing 16% ethylene this would be equivalent to 100 p.p.m. of ethylene. The fact that the calculations and measurements were exact enough is demonstrated by a gas analysis made on a sample of the gas taken at the time the flowers were placed in the drum. The analysis showed 98 p.p.m. of gas; a second sample taken when the flowers had been in the drum for 20 hours showed a drop to 80 p.p.m. This may have meant that the flowers absorbed the difference. The flowers were removed after 20 hours, and two days after treatment 7 of the 12 flowers were sleepy.

FIGURE 2. Photographed four days after being subjected to 250 p.p.m. of pintsch gas (equivalent to 40 p.p.m. of ethylene) for 10 hours. Left—5 flowers showing sleepiness. Right—7 flowers normal.

This number gradually increased until six days after treatment only 1 flower was not sleepy. The concentration of gas used was gradually reduced to 200 p.p.m. of pintsch gas (equivalent to 32 p.p.m. of ethylene) to which the flowers were subjected for twenty-four hours. Within one day after treatment practically all the flowers showed sleepiness and in two days all were definitely sleepy.

In all these tests the flowers were given good care throughout. After picking they were held in water in a cool cellar at 40° to 45° F. for 24 hours to avoid the sudden shock of submitting them directly to gas treatment.

When packed for treatment wet newspaper was placed about the stems. After treatment the stems were trimmed and the flowers put in cool water and set in a cool greenhouse for at least 24 hours before placing them near any of the other flowers. However, the approach of spring weather with longer hours of sunlight resulted in considerable fluctuation of the temperature in the greenhouse, varying from 40° F. during the night to 75° F. during the day. It seemed possible that the higher temperature might increase the harmful effect of the gas. To offset this possible effect the drum was removed to a refrigerated room kept at a constant temperature of 50° to 52° F. This temperature was chosen because previous investigation revealed that the temperature inside the flower cartons when placed

FIGURE 3. Same flowers, as shown in Fig. 2, photographed two days later. Left—8 flowers showing sleepiness. Right—4 flowers normal.

under the tarpaulin in the express cars was between 55° and 60° F. This temperature tended to remain above or about 50° F. for about 20 hours afterwards. A number of the tests were repeated under these conditions. After treatment the flowers were trimmed, put in water and placed in a cool greenhouse.

The highest concentration used was an amount of gas measured to give 500 p.p.m. of pintsch gas (equivalent to 80 p.p.m. of ethylene). Flowers subjected to this treatment for 24 hours showed 3 sleepy and a number of the remainder doubtful within one day after treatment. Within two days only 1 flower was still healthy and within three days all were sleepy. Reduced concentrations of gas were just as effective in causing sleepiness.

The lowest concentration used was 100 p.p.m. of gas (equivalent to 16 p.p.m. of ethylene). Actual analysis of the gas in the drum showed 27 p.p.m. at the start and 32 p.p.m. after 24 hours. This may have been due to other harmless gases being present, but even so it is well within the range of analyses made on gas samples from the express cars as shown in the preceding table. This concentration of gas caused sleepiness in 8 of the 12 flowers within one day after treatment, and within two days all were sleepy except one.

Similar tests were carried out in which the flowers were subjected to gas treatment for 10-hour periods. In most cases the effect upon the flowers was not quite as severe as the 24-hour treatment, but was sufficient to cause considerable sleepiness to develop. The lowest concentration used in these tests was 250 p.p.m. of gas (equivalent to 40 p.p.m. of ethylene). Actual analysis showed 41 p.p.m. at the start and 34 p.p.m. after 10 hours. Apart from a doubtful appearance observed in some of the flowers complete sleepiness was not observed until the fourth day after treatment when 5 of the 12 flowers showed severe sleepiness. Two days later only 4 of the 12 flowers were not sleepy.

In all these tests with pintsch gas care was taken to ventilate the steel drum thoroughly in fresh air for at least one day between each test. This not only removed all traces of gas used in the preceding test but also filled the drum with clean air. At frequent intervals during the tests flowers were placed in the drum and put through all the steps with the only difference being that no gas was added. These flowers served as checks against which the gassed flowers were compared. In no case was sleepiness observed in any of the check flowers even after as long as ten days.

CONCLUSIONS

There is some factor present in the shipping of carnations by rail which may at times be sufficiently great to affect the carnations and cause sleepiness.

The gas ethylene will definitely cause sleepiness. This gas is one of the constituents of pintsch gas used so frequently on the railways and used for lighting and cooking in some of the express cars entered during these investigations.

Exposure of carnations to such small concentrations of pintsch gas as 100 p.p.m. (equivalent to 16 p.p.m. of ethylene) for 24 hours and 250 p.p.m. (equivalent to 40 p.p.m. of ethylene) for 10 hours caused severe sleepiness. There is no reason to doubt that even smaller concentrations of the gas would also cause some sleepiness. These concentrations are within the figures obtained for analyses of gas samples collected in the express cars.

At the larger railway stations where there are gas outlets for charging the railway cars there is very frequently a strong odour of the gas present. This gas may diffuse through the express sheds where flowers are brought for shipment or on arrival, it may diffuse through the packages while being transferred to the cars, or it may diffuse through the cars, even those not using pintsch gas, while they are being loaded.

There is no reason to believe that sleepiness in carnations is the result of growing or cultural conditions.

POSSIBILITIES FOR CONTROL OF SLEEPINESS

It should be possible to prevent sleepiness by preventing harmful gases coming into contact with the flowers. The packages of flowers, particularly carnations, might be stacked in a reasonably air-tight container on arrival at the express sheds. Such a container could be equipped with a ventilating attachment which would remove harmful gases, especially the unsaturated hydro-carbon gases, before passing air into the container.

FIGURE 4. Flowers exposed to 200 p.p.m. of pintsch gas (equivalent to 32 p.p.m. of ethylene) for 24 hours. Photographed two days after treatment. Left—10 flowers showing sleepiness. Right—2 flowers normal.

During the investigations some preliminary tests were made with carnations subjected to gas treatment at a temperature of 43° to 45° F. without any signs of sleepiness developing. This indicates that there may be a critical temperature above which pintsch gas produces sleepiness and below which it has no effect. If this should be so, temperature control of the flowers may furnish another means of preventing pintsch gas from affecting carnations.

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REFERENCE

1. CROCKER, WM., and L. I. KNIGHT. Effect of illuminating gas and ethylene upon flowering carnations. Bot. Gaz. 46 : 259-276. 1908.

BOOK REVIEWS

SOILS AND FERTILIZERS. By Firman E. Bear, Professor of Agricultural Chemistry, Rutger's University. Soil Chemist, New Jersey Agricultural Experiment Station. Third Edition, XI + 374 pages illustrated. Published by John Wiley & Sons, Inc., New York, 1942. $3.50.

Published in two previous editions under the title "Soil Management" this popular text and reference now appears in the Third Edition under the new title "Soils and Fertilizers". The author states in the preface, "This change was decided upon because of the ever increasing importance of lime and fertilizer materials as aids in maintaining and increasing the productivity of soils and because the book deals in a considerable part, with these materials and their uses."

Upon superficial examination it might appear that, other than this, few changes have been made in this new edition. Except for the omission of the five general divisions previously used, the contents list the same headings for the 26 chapters as in the second edition. The adoption of a different type and composition, although resulting in a reduction of over thirty pages in volume, apparently has made possible not only the inclusion of the bulk of the original subject matter but the introduction of new material as well.

A more careful examination reveals that numerous changes have been made throughout the text to bring it up to date. The author has replaced several tables of data, and numerous photographs and illustrations, with new material considered to be better adapted for the purpose. The discussion relating to soil classification has been greatly improved by the adoption of the newer concepts and the inclusion of a new double page map of the Great Soil Groups of the United States. Such topics as colloidal material, base exchange, etc., although discussed briefly, are treated in the light of more recent knowledge concerning their importance in soil processes. New material has been introduced in the discussion of fertilizers and some changes in terminology adopted. Fertilizer ratios are discussed under general recommendations in place of standard analyses.

Determining the fertilizer needs of soils by rapid soil and plant tissue tests, and the use of plant symptoms in soil diagnosis, are new topics introduced into the chapter on the selection of fertilizers. A brief outline is given also for the method of calculating indexes of productivity for different systems of soil management. In keeping with the changes in text, the selected references listed at the end of each chapter have been revised and added to so that the more recent literature on many topics is now included.

Although intended primarily as a text or reference book for students in agricultural colleges taking a first course in soils, this third edition should prove useful to others who may be directly or indirectly interested in the practical problems involved in maintaining the productive capacity of our soils. Teachers of agriculture in secondary schools, agricultural representatives and other extension officers should find "Soils and Fertilizers" a worthwhile reference.

G.N.R.

WEEDS. W. C. Muenscher. The Rural Science Series, edited by L. H. Bailey, New York: The MacMillan Co., $5.00.

The excellent manual, *Weeds*, by Professor W. C. Muenscher, Cornell University, a review of which appeared in *Scientific Agriculture* Vol. 16 : 5, 1936, has been reprinted for a second time since its publication less than five years before. What was said in reviewing it then has been fully justified in the light of constant use since; no serious flaws have become evident. From the standpoint of the weed specialist possibly the least used feature of the book is the key, running to 35 pages; but for the less versatile student such an aid could not well be dispensed with. These particular years have been a period of active experiment in chemical weed warfare but the treatment of the subject is not yet seriously out-dated. The emphasis placed on the chlorates is negatived now to some extent by the exigencies of wartime, helped by at least some advent of alternative herbicides. When the time comes for a revision of the text this phase of the subject of weed control may be, more than now, one of those inviting attention. A reduction in price to $5.00 brings the book within reach of a wider circle of readers.

H. GROH.